Electrochemical Industry

VOL. I. PHILADELPHIA, FEBRUARY 1, 1903. NO. 6.

Electrochemical Industry

Published on the first of each month by the

ELECTROCHEMICAL PUBLISHING COMPANY,

[*Incorporated.*]

CITY TRUST BUILDING, PHILADELPHIA, PA.

J. W. RICHARDS, PH.D. . . . . *President.*
E. F. ROEBER, PH.D. . . . . *Editor.*

Long Distance Telephone 3-51-24.

Subscription Price: $2 per year, postpaid to any part of the world. Single copies, 25 cents.

ADVERTISING RATES GIVEN ON APPLICATION.

Entered October 24, 1902, at Philadelphia, Pa., as Second-Class Matter, under Act of Congress of March 3, 1879.

CONTENTS.

ELECTROPLATING.

In this issue we print several articles on the practice and theory of electroplating, which we trust may prove interesting to the practical electroplater, as well as to the electrochemical scientist. With the only exception of the battery industry, electroplating is the oldest electrochemical industry; it also is a large industry, there being more than 1,100 electroplating firms in the United States alone, and the products of this industry are in general use. This industry, however, has developed as a separate industry, touched but faintly by the development of other electrochemical industries, and practically unaffected by the progress of electrochemical science. In the electroplating industry, the rule of thumb has been reigning supreme for many years, although recently signs of improvement and healthful progress are plainly evident. But the improvement is due to the introduction of improved apparatus rather than to a better understanding of the principles of electroplating.

The methods and apparatus formerly used by electroplaters were extremely rude. Mr. H. L. Haas, in an article published in this issue, sketches in an amusing manner the method by which in former years an electroplating solution was generally made up by the workingman who had to attend to it. It is a great advance that electroplaters now appreciate the importance of weighing the various materials which they put into the solution. They now understand that to get good results they must exactly know the composition of the solution when they start the operation. Another advance of equal importance is that the electroplater now also recognizes the necessity of carefully producing and maintaining the electrical conditions required to get the desired result. The old-time plater's voltmeter was an old rusty file which they used to put across the two wires, making the connection and getting a spark; then they knew the electric current was flowing, but that was all they knew. In recent years exact measuring instruments are being largely introduced in electroplating establishments; complete switchboards with instruments and rheostats are in the market, specially designed for the convenience of the plater. The design of electroplating dynamos was also materially improved. The result is that the electroplater is now in a position of knowing exactly the conditions of his operation. By weighing the materials and following exactly the instructions regarding the arrangement of the plant and the regulation of voltage and current, a careful attendant will get good deposits —even though he may not know anything about the principles of electrolytic action. This is surely a great practical advance and accounts for the improved results obtained in recent years. But while it would be folly not to appreciate the great practical importance of this progress, yet it is necessary to emphasize that a more important advance must still be made; that is, all of us have still much to learn concerning the fundamental principles underlying this subject.

It is certainly a good thing to know exactly the conditions under which a good adhesive deposit is obtained, and to know that by changing the conditions the deposit changes in a certain way. Such knowledge is the result of careful observations and long practical experience. But to apply such knowledge to other different cases, it is necessary to know *why* the deposit is good under certain conditions and poor under others; *i. e.*, it is necessary to understand the general theoretical principles underlying the electrolytic deposition of metals. It is but fair to confess our ignorance of these principles in many respects. Future progress depends upon the co-operation of the practical electroplater and the theoretical scientist; in order to promote such co-operation, we publish the articles on electroplating in this issue, and we hope that they may interest both practical men and scientists in the fascinating problems involved in electroplating. A better understanding of these problems is sure to bring about fruitful results for theory, as well as practice.

At first sight, when viewed from a theoretical point of view, the process of electroplating seems to be one of the simplest cases of electrochemical action, but when studied more accurately it is found to be very complicated. The chemical nature of the electrolyte, the chemical nature of the metal to be deposited, and that of the metal upon which the deposit is to be made, the concentration of the electrolyte, the current density and the temperature, all are found to be important factors influencing the properties of the deposit obtained. We know that distinct relations exist between these factors and the properties of the deposit obtained, but we understand these relations only in part. Various interesting observations, mentioned in the articles on the following pages, illustrate this point very clearly.

That the chemical nature of the electrolyte is of the utmost importance, was long known among electroplaters; in fact the patent literature of electroplating is practically a long series of recipes for plating solutions. We know that in many cases certain additions are of great advantage, but we are still more or less in the dark why it is so. For instance, Prof. C. F. Burgess and Mr. Carl Hambuechen, in their article in this issue, mention that a small quantity of carbon bi-sulphide in a silver-plating solution enables a polished coating to be obtained, whereas when omitted the surface would become rough much more quickly. These authors point out that viscosity and surface tension of a solution seem to have some relation to the quality of the deposit; if a substance is added to a metal salt which alters these properties, the quality of the deposit may be influenced. The same authors point out that the quality of the deposit depends upon the degree to which the plating solution wets the surface of the cathode. It is quite evident that to get a good deposit, the solution should thoroughly wet the entire surface; hence, as this property can be imparted by additions of other soluble substances, their addition will improve the deposit. The same authors mention a very peculiar experimental fact: the kind of deposit which was obtained from a zinc sulphate solution prepared by dissolving crystals of zinc sulphate in water was found to be materially different from the deposit obtained under similar conditions of temperature, current density and contents of solution, in which case, however, the solution was prepared by dissolving pure zinc in dilute sulphuric acid until it became of the same neutrality as the solution obtained by dissolving the crystals.

Mr. Woolsey McA. Johnson discusses the same problem—the influence of the chemical nature of the solution—from the point of view of the electrolytic dissociation theory. He calls attention to the fact that double salts are found to give good results in practice, and he advances the view that these good results are due to two different causes: to the increased cathode-potential, and to the fact that the double salt always furnishes the catholyte with a good supply of cations by its continuous decomposition. It will be seen that the influence which the chemical nature of the solution has upon the quality of the deposit, may be considered from very different points of view, and it is quite probable that when this matter will be better understood in future, it will be found that here a great many different influences are playing a role.

The influence of the chemical nature of the metal to be deposited and of the metal upon which the deposit is to be made, is discussed in an interesting article by Dr. Louis Kahlenberg. He points out that the alloying power of the electrolytic deposit with the coated metal underneath is a factor determining not only the strength with which the deposit adheres, but also the length of time the plated article will wear and resist corrosion. There is a tendency of the two metals to dissolve in each other, a tendency of mutual interpenetration of their masses. The stronger the affinity of the metals for each other is, the better the deposit is apt to adhere; a clean, slightly roughened (etched or scratch-brushed) surface facilitates alloying. The practical conclusion reached by Dr. Kahlenberg is to plate those metals or alloys upon each other that possess sufficient affinity to coalesce well, and yet will, at the temperature at which the plated objects are to be kept, diffuse but very slowly into each other.

Prof. Burgess and Mr. Hambuechen discuss the same subject, but think that the alloying phenomenon cannot be held as a universal one. They assume that in some cases no formation of an alloy takes place, but direct cohesion, which is established when solid particles are brought into intimate contact. However that may be, it is certain that what is needed, is intimate contact between the molecular particles of the one metal with those of the other metal—not branches, twigs and outgrowths, but rather roots and a dense undergrowth.

PATENTS AS LITERATURE.

The United States has issued, to date, upward of 700,000 patents, each of which presumably embodies an original idea, of which the individual patent is a full and adequate expression. These patents are classified according to the several arts, and the vast mass of material so collected constitutes a rich field for study and investigation.

This patent literature, however, does not consist in general of a series of accurate and conservative monographs; it is rather, for the most part, in the form of more or less fragmentary notes written by the inventor, or, at least, from the inventor's viewpoint, and expressing not so much the accomplishment of a result as the formulation of a hope.

Of course, there are exceptions—descriptions so clear and convincing that the patent specification is what the law intended that it should be, a clear expression and definition of the patentee's contribution to progress. Too often, however, the description is a recital of imaginary defects of the devices of the prior art and illusory advantages of the new construction. In such cases an effort to attain any clear idea of the practice of the day or of the development of a given principle, through a study of the patents alone, will be futile.

This is unfortunate, but in large part it is irremediable. The average inventor is often characterized as visionary, which is true in part only. More accurately, his dominant characteristic is hopefulness, and no law exacting accuracy will ever prevent him from painting his thought with the bright colors which, to him, are real. To read patents with profit, one must understand this and sympathize with it; one must see with the inventor's eyes in order to understand his thought. Then whatever of value or suggestiveness the idea may contain will become clear.

ON ENTROPY.

A very animated and amusing war on entropy is raging at present in our British electrical contemporaries. In a note in his recent presidential address to the (British) Institution of Electrical Engineers, Mr. James Swinburne claimed that nearly all text-books are wrong in defining entropy. This remark elicited a sharp answer by Past President Prof. John Perry, which was followed by others, and the war is still going on merrily. If it was simply a quarrel on technical terms, a new case of the tower of Babel, there would be no use in saying much about it; we could simply mention that Mr. Swinburne claims to base his views directly upon Clausius, who coined the term and established the second principle of thermodynamics; and that, according to Professor Perry, it is a matter perfectly well known that Clausius used a term in one sense and all modern men use the same term in another sense (the term "all modern men" being again open to discussion); and that Lord Kelvin says entropy is Clausius' word, and persons concerned in it will find its definition in Clausius' own writings.

However, it is not simply a quarrel about words. If we understand Mr. Swinburne correctly, he wants to protest against the predominant place which is given to reversible processes in the discussion of the second principle of thermodynamics in ordinary engineering text-books. He wants to emphasize that reversible processes are only an ideal case, never fulfilled in practice, and that, in fact, the cardinal point of the second principle of thermodynamics is that in nature we always have irreversible processes, in which the entropy always increases. And in this respect Mr. Swinburne is right, without doubt. The well-known integral representing the heat supplied from an outside reservoir to the system under consideration, divided by the absolute temperature at which this heat exchange takes place at any moment, serves only as a method of determining the value of the entropy, and it is here an essential supposition that the process by which the system is brought from one condition to another is absolutely reversible. Thus the reversible processes serve only for determining the value of the entropy, but in nature we have only irreversible processes.

The difficulty in the whole matter seems to arise from the fact that the value of entropy is found by determining the value of the integral mentioned above for a reversible process. Being thus mathematically defined, its physical meaning is obscure. We here arrive at a limit of our knowledge. We can give the value of entropy, independently of that integral, only for gases and dilute solutions, but in all other cases we must go back to that integral. Nevertheless, we should take pains to connect a physical meaning with the word entropy. If we do this many misunderstandings will disappear, and especially the fundamental difference which exists between the principle of the conservation of energy and the principle of the increase of entropy will become evident; that is, the difference between the first and second principles of thermodynamics. It is still too often thought that the second principle of thermodynamics is only an appendix to the principle of the conservation of energy, while, in fact, it states something with which the energy principle is not at all concerned.

If an isolated system is given which passes from one condition into another, the first principle of thermodynamics states that the energy of the system in one condition is exactly the same as in the other. Viewed from the principle of the conservation of energy, there is no preference for either condition; both are equivalent, and in both the system has the same energy. But we know that a change will always take place in a certain direction, and not in the opposite direction. The energy principle does not indicate in any way what this direction is, but the second principle of thermodynamics does. This is indeed the fundamental point of this principle. We can accordingly give a popular definition of entropy, which we believe is due to Planck. It is that the entropy of a system is the function representing the preference which nature gives to one condition of the system above another condition. Entropy will therefore always increase. To mention one instance, if we have two solutions of the same electrolyte, but of different concentrations, this system of the two solutions has a certain entropy. When the two solutions diffuse, the entropy increases, because this is an irreversible process. Hence the process will always take place in such a direction that the dilute solution becomes more concentrated, and the concentrated solution more dilute. This enables us, for instance, to always predict the direction of the e. m. f. in a concentration cell, and it is absolutely wrong to assume that it is of any influence whether the heat of dilution is positive or negative. It is true Berthelot believed that the direction of a chemical process is determined by the amount of heat which the action can evolve; the reason why hydrogen and oxygen combine and form water, and why not the reverse takes place, is, according to Berthelot, that the former process evolves heat. True, this view has been predominant in thermo-chemistry for many years. But we know now that Berthelot's principle is wrong as a general principle, and in its place we have the second principle of thermodynamics; a chemical process takes place in such a direction that the entropy increases. We hope to return to this point in connection with some special electrochemical subjects in future issues.

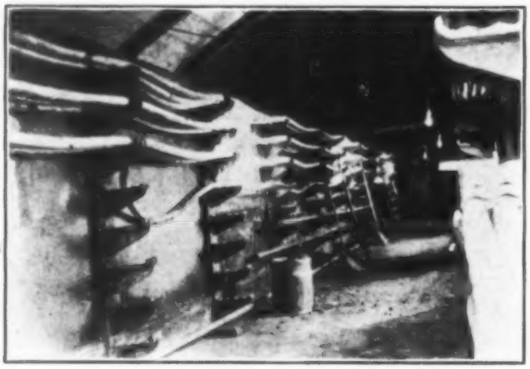
NIAGARA POWER PLANT COMPLETELY SHUT DOWN BY FIRE.

By Frank C. Perkins.

The thunder shower of Thursday, January 29th, damaged the 75,000 horse-power Niagara Falls power plant to such an extent that it was necessary to stop every one of the fifteen 5,000 horse-power alternating-current generators. All of the current from the 50,000 horse-power plant in power house No. 1 passes through the cable bridge, carrying the current from the power house to the step-up static transformers in the transformer house across the canal. The temporary connections of the new power house No. 2 were also of such a nature that the fire which occurred in the cable bridge and transformer house made it impossible to utilize these machines.

It is believed that a stroke of lightning formed a serious short circuit in a 2,200-volt local circuit in the cable bridge, and the roof of the bridge, which was of wood, took fire, as well as that of the transformer house, resulting in the destruction of every high-tension lead-covered cable between the power house and the transformer, shutting down the entire plant.

In extinguishing the fire large quantities of water were poured into the transformer house, badly damaging the air-cooled transformers, which were located near the entrance to the cable bridge. It is thought that little damage was done to



CABLE BRIDGE ON THE MORNING AFTER THE FIRE.

the oil-cooled transformers by the fire, and the air-cooled transformers may be serviceable as soon as thoroughly dried out.

The accident happened about midnight, and the quick work of Superintendent Philip P. Barton and his men resulted in the replacing of 36 of the cables before morning and the replacing of a temporary roof on both bridge and transformer house, and four 5,000 horse-power machines were in operation.

Of the total 75,000 horse-power generated in the two power houses, about one-third is transmitted over the 22,000-volt lines to Buffalo for operating the street railways and lights of the city, as well as furnishing power to many of the newspaper establishments and various factories. The storage-battery plants of the International Railway Co. and the Buffalo General Electric Co. were of service for several hours, and the large reserve steam plant of the railway company was soon placed in operation and the car lines were never all shut down.

The arc and incandescent-lighting service of Buffalo and Tonawanda was not so fortunate, and both cities were without light until Thursday evening.

The power plant of the Niagara Falls Hydraulic and Mfg. Co., which obtains its power from a surface canal through the city of Niagara Falls, was able to render great assistance during the trouble, and the lights of that city were kept in operation, as well as the street railway service.

It is stated that the damages will probably exceed $50,000, and undoubtedly as much again if the losses of the tenants and other power users is considered. The construction of the bridge and transformer house is entirely of iron and stone, except the roofing, which is of wood. And while the fire itself caused little or no damage to the transformer plant, the water, of course, put the transformers of the air-cooled type entirely out of service for the time being. Had tile or other fire-proof roofing been used, undoubtedly the damage would have been much less, and might have saved the plant from being entirely closed down. A second conductor bridge, with duplicate cables, would unquestionably have rendered the accident less serious, as "all of the eggs would not have been in one basket," and the current might have been sent to the transformer house through the second set of conductors.

It may also be considered doubtful whether it is wise to place all of the transformers of a 50,000 horse-power plant in a single building, as the burning out of one or more may affect a number of others. This disastrous fire at the Niagara Falls plant shows how much care is necessary in the protection against lightning and the desirability of using fire-proof materials in every portion of a modern electric power plant.

The duplicating of transmission lines is now extensively practiced, and is undoubtedly advisable. And there is little question but that the engineers of the five new plants being constructed on both sides of Niagara River, above and below the falls, will carefully consider the causes of this serious shut-down in all its phases, and endeavor to make such provisions that a similar accident will be impossible.

The engineers of the Niagara Falls power plant are to be congratulated on the rapidity with which they were able to place their power lines in service again after so serious an accident. This is, however, characteristic of electrical engineers in both lighting and power plants. They usually are equal to almost every emergency, no matter how serious it may be. The accompanying illustration shows the interior of the cable bridge the morning after the fire, with new cables in place and roofing completed.

PROPOSED (BRITISH) SOCIETY OF ELECTRO-CHEMISTS AND METALLURGISTS.

At a meeting of the Provisional Committee of the proposed (British) Society of Electrochemists (see Electrochemical Industry, Vol. I, page 4, Sept., 1902), held on January 6th, Mr. James Swinburne in the chair, it was resolved, in consideration of the support and encouragement received in response to circulars recently issued, to hold, on February 4th, a general meeting of the supporters of the movement and formally inaugurate the work of the Society and elect a president and council.

It has been suggested that there should be two classes of members—members and associated members—the subscription fees being two guineas and one guinea respectively (*i. e.*, about $10 and $5).

The honorable secretary of the Provisional Committee is F. S. Spiers, 82 Victoria street, London.

The following gentlemen have consented to be nominated as members of council of the proposed society: President, J. W. Swan, F.R.S.; vice-presidents, Prof. A. Crum-Brown, M.D., D.Sc., F.R.S., Sir Oliver J. Lodge, D.Sc., F.R.S., Dr. Ludwig Mond, Ph.D., F.R.S., Lord Rayleigh, D.C.L., F.R.S., Mr. Alexander Siemens and Mr. J. Swinburne; council, Messrs. George Beilby, Bertram Blount, W. R. Cooper, M.A., B.Sc., Sherard Cowper-Coles, A. G. Charlten, F. G. Donnan, M.A., Ph.D., Prof. A. K. Huntington, F. Mollwo Perkin, Ph.D., W. S. Squire, Ph.D., and O. J. Steinhart, Ph.D.

Statistics of Electroplaters.—Census Bulletin No. 150, issued September 15, 1902, gives the number of electroplating firms in the United States in 1880 as 221, and in 1900 as 422, the value of their products being given as $1,975,700 and $3,007,455 respectively. The number of "galvanizing" firms in 1900 is given as 28, and the value of their products as $2,470,-703. It seems that these figures are too low, for, according to reliable private information, there are more than 1,000 electroplating firms in the United States.

THE ALLOYING OF METALS AS A FACTOR IN ELECTROPLATING.

By Prof. Louis Kahlenberg, Ph.D.

At the meeting of the American Electrochemical Society, at Niagara Falls, Professor Haber demonstrated experimentally that when an aqueous solution of a salt of sodium or potassium is electrolyzed, using a cathode of tin or lead, hydrogen is formed, and a dark cloud, consisting of the finely-divided heavy metal, envelops the cathode. With a lesser current density, the cloud does not form, the surface of the heavy metal being simply roughened. It was pointed out by Professor Haber that here the alkali metal actually is deposited on the cathode, forming an alloy with the latter, which is then decomposed by water, yielding hydrogen secondarily and the finely-divided metal. This experiment is of great value in settling the mooted question of whether the hydrogen liberated at the cathode during the process of electrolysis of an aqueous solution of a salt of an alkali metal is of primary or secondary origin. While, as Professor Haber stated in the conclusion of his paper, the experiment is perhaps of more theoretical than practical interest, nevertheless it is simply a striking illustration of a general fundamental principle that underlies all electrolytic deposition of metals.

When one metal is deposited electrolytically upon another, the process of alloying always goes on to a greater or less extent, which is determined primarily by the nature of the metals, and secondarily by the conditions of experiment. Among the latter are of special importance the original condition of the surface of the cathode, nature and concentration of the electrolyte, temperature, potential and current density. These all have been well recognized and thoroughly discussed in text-books as important factors in securing desirable, dense, well-adhering deposits that will admit of being polished and burnished. The important fact that the alloying power of the electrolytic deposit with the coated metal underneath is a factor determining not only the strength with which the deposit adheres, but also the length of time the plated article will wear and resist corrosion, has not been sufficiently recognized.

The alloying power of two metals consists of a specific attraction of the metals for each other, a tendency to dissolve in each other, or, as it is put by others, a tendency that the metals have to bring about a mutual interpenetration of their masses. This force is no doubt chemical in character, slight though the affinity may be in some cases. The alloys of mercury, the amalgams, especially those of the alkali metals, have become of considerable importance in the electrolytic preparation of caustic alkalies and of alkali metals. Here the alloying of the alkali metal with the mercury constituting the cathode is well recognized. But when gold is plated on lead, for example, an alloy of gold and lead is just as truly formed at the point of contact between the two metals. A thin plating of gold on lead will gradually soak into the lead entirely as the alloying process continues. This goes on at room temperatures. The experiments that Roberts-Austen made in 1900 ("Proceedings of the Royal Society," London 67, 101-5) demonstrating how gold diffuses into lead at ordinary temperatures are of special interest in this connection. A thin plating of gold on zinc is absorbed in a few days. The "tarnish" becomes visible very soon. After the deposit has been absorbed, the gold may be exposed again by carefully etching away the zinc from the surface by use of a dilute acid. The experiment of Gore, illustrating how copper plated on platinum penetrates into the latter, is well known to electroplaters.

This affinity between metals asserts itself the moment one metal is deposited on the other. The stronger the affinity of the metals for each other is, the better the deposit is apt to adhere. On the other hand, the plating is also more apt to be absorbed by the base metal underneath the greater the tendency of the metals to alloy is. A higher temperature generally aids this alloying process, and so it is that frequently much better adhering deposits are obtained by working at temperatures above the ordinary. A clean, slightly roughened (etched or scratch-brushed) surface of the cathode clearly facilitates the alloying of the deposit with the metal of the cathode, for thus a more intimate contact is secured. When two metals are to be alloyed under ordinary conditions, the affinity between them must overcome their cohesions. This frequently requires a high temperature. In the process of plating the affinity between the metals clearly does not initially have to overcome the cohesion of the deposited metal, since the latter is gradually built up, starting with an exceedingly thin film. Thus it is that alloys of metals may readily be formed at room temperatures by electrolysis, whereas under ordinary conditions the alloys would not form at all, or would form but very slowly. The fact that platinum will not amalgamate with mercury under ordinary conditions, and that platinum amalgam may readily be prepared electrolytically, is a good illustration of this.

In the case of any plated article, the deposit and the metal underneath continue to act upon each other, or mutually diffuse into each other. This action is great between zinc and gold or lead and gold, as has been stated above. Between copper and gold and brass and gold it is less noticeable. And yet who has worked with brass, gold or platinum-plated weights and has not noticed that the plating is, after all, but a relatively poor protection against corrosion? Especially as the weights grow older they are all the more easily corroded by moisture and traces of salts in the atmosphere of the laboratory. If the plating is heavy, this corrosion will, of course, not take place so early as when the coating is thin, which is so frequently the case.

The mechanical character of the alloy formed by the deposited and the base metal is also of practical consequence. If the alloy has a strong tendency to become crystalline, or is brittle, or has a considerably different co-efficient of expansion from that of the pure metals, the deposit is more apt to chip off than if the alloy is pliable and does not exhibit tendency to crystallize.

Nickel may be successfully plated on copper and its alloys—brass, bronze, etc.—for with these nickel alloys readily. On the other hand, when an object of lead is to be nickeled, it is first copper plated, and then the nickel is deposited on the copper. In this operation use is made of the fact that copper alloys readily with nickel, and copper alloys better with lead than does nickel; and so copper serves here as a cement, as it were. Many other similar illustrations from practice might be cited.

In general, then, metals that will alloy readily with each other may, other things being equal, successfully be plated on each other. Whether the plating will be absorbed faster or slower will depend on the character of the metals and the temperature at which the object is kept, as noted above. If the deposit consists of a metal of the same color as the base metal underneath, as, for instance, gold over brass or copper, the effect of this diffusion of the metals into each other will not be so apparent as when the metals are of different hue—gold on lead or zinc. And yet metals of very different color may at times be plated on each other, and the effect of this diffusion remains unnoticed because the alloy formed has the color of the plating even up to very high concentrations of the alloy. Nickel on copper is a good illustration of this.

While it thus appears that a strong alloying power is desirable between base metal and electrolytic deposit, as it tends to secure good adhesion of the latter, it is also evident that this tendency to form an alloy frequently militates against the very purpose for which the electrolytic deposition was made, namely, to secure a better appearance or to protect from corrosion. It is evident that in the long run all plated objects must slowly deteriorate, even when not in use and when carefully protected from the atmosphere by a lacquer of some kind. The electroplater must study the subject carefully so as to plate those metals or alloys upon each other that possess suffi-

cient affinity to coalesce well, and yet will, at the temperatures at which the plated objects are to be kept, diffuse but very slowly into each other. He will also choose the color of the metals or alloys so that the final alloy formed may have the same, or nearly the same, shade as the electrolytic deposit and will itself be corroded less readily than the base metal alone.

The connection between soldering and electroplating of metals is evident from what has been stated. So, for instance, the difficulty of plating on aluminium and of soldering the metal go together, though, of course, the fact that this metal is readily oxidized, and that the oxide coating interferes with both processes, must not be lost sight of. It is not so easy to solder iron with the usual half-and-half solder, as it is to solder zinc, though the latter metal is much more readily oxidized than iron. The explanation is clear: iron does not alloy as readily with the tin and lead solder as does zinc.

A careful, systematic study of the electrolytic deposition of the metals from the standpoint of the alloys formed will no doubt yield results of further practical value.

LABORATORY OF PHYSICAL CHEMISTRY,
University of Wisconsin, Madison.

THE SMELTING OF IRON ORES AND THE PRODUCTION OF STEEL IN THE ELECTRIC FURNACE.

By MARCUS RUTHENBURG.

The application of electricity to the smelting or iron ores or the production of steel, either from the ore or previously smelted pig iron, is not a matter of merely recent endeavor.

Attempts, more or less successful, have been made for a number of years in this direction, more especially in Europe, where proper fuel was deficient or too costly, and where water-power, cheap in comparison with available fuel, could be readily obtained.

Therefore, it has been broadly stated, that it was only in such an environment that the electrical production of pig iron or steel could be carried out, upon a commercially successful basis.

In this country, near Niagara Falls, there has been for several years, in intermittent operation, a plant for the production of special alloys of iron. The operator of this plant, in a lengthy and learned article, in a recent issue of *The Iron Age*, went into the subject of the smelting of iron ores electrically, exhaustively, and proved theoretically and practically, that it required the continuous expenditure of 200 horse-power, to produce one ton of metallic iron in twenty-four hours. In other words, that it required 4,800 horse-power hours. Stassano, in Italy, claims to smelt a ton of finished product with 3,000 horse-power hours. De Lavel, in Sweden, calls for 3,500 horse-power hours, and Rossi at Niagara Falls uses 4,800 horse-power hours. I have thus set forth what the more prominent experimenters and operators have claimed for themselves, not with the object of invidious comparison, but to state clearly what you might call the condition of the art.

In France, three separate and distinct plants have more recently been put in operation with power consumption differing not materially from the above.

How their conclusions as to power consumption have been arrived at, is a detail that none of them have enlightened the public upon. More than likely it has been done by taking periodic readings of voltmeters and ampèremeters, which is far from conclusive, as both volts and ampères are given to fluctuations, both sudden and excessive, leaving to the one taking the readings the exercise of his judgment as to what the reading should be.

Using a recording watt meter is the only way that this power consumption can properly be arrived at. It takes cognizance of pressure, current and time, and all the attendant has to do is to read his meter and weigh his product.

Before describing some of my own work in electrical smelting of iron ores, there is another point that I want to call attention to, and that is the cost of electric current per kilowatt hour, or per horse-power hour. So many people are in the habit of pointing to Niagara Falls as the place of all places, to secure an unlimited supply of electric current, at economical, if not cheap prices. Cheapness must always be comparative, that is, something is cheap, when of equal quality it can be produced for less in one place than another.

I have long asserted that in their anxiety to get something for nothing, engineers have rushed to remote and out-of-the-way places to capture a promising water-power, and ignored what could be accomplished with large steam actuated electric units.

Let any of these gentlemen figure up what a kilowatt hour can be produced for, based upon the coal consumption and cost of operation and maintenance of a 1,000 or still better a 5,000 kilowatt unit. He will then find that a fair quality of coal, with the facilities that any large plant would of necessity be provided with, will put the prices now asked by prominent water-powers, very much in the shade.

My own work in the electrical smelting of iron ores has been of a practical nature, and my efforts have been bent to the accomplishment of the work upon a basis that would not only permit of universal use of the method, as an offset to blast furnace and open hearth steel practice, but would also produce superior metal at a materially less cost. In a nutshell, this statement resolves itself into a question of how much power I use to accomplish my work, and in a nutshell

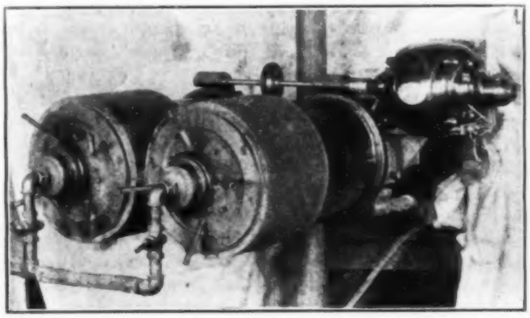


FIG. I.—VIEW SHOWING BRIDGE OF ORE BETWEEN ROLLS.

the answer is, less than 500 kilowatt hours to produce a ton of product.

Some very learned gentlemen have undertaken to prove that "this was not possible"—that "it was an unheard of efficiency," and that "even if it were so, the vast stores of high-grade ores at our command and the efficiency of the blast furnace made the man who offered to replace the blast furnace simply a happy optimist." To these gentlemen let me simply say, show me the supply of high-grade ore, open to the independent operator, and I will undertake to "make him rich beyond his dreams of avarice." As to the economy of the blast furnace the same learned gentlemen will agree with me, that of the ton of coke, which even good practice requires to make a ton of pig iron, but a little over 300 pounds are required for the chemistry of the furnace, *i. e.*, reducing the iron. The balance is required to melt not only the reduced iron, but the medley of earths and the lime which go to form the cinder. An important portion is also consumed in the production of waste combustible gas, some of the value of which is recoverable under boilers and in the stoves for preheating the blast. As against this, what is a fair statement of the operation of an electric furnace producing a ton of metal with a consumption of 500 kilowatt hours.

The 500 kilowatt hours will require the combustion of 1,000 pounds of soft coal (not coke). The reduction of the ore will

require 300 pounds of carbon = 700 pounds of fuel, saved at the outset. At the present abnormal prices of coke and coal any comparison of price would not be of any particular moment, though ordinarily coke costs about twice as much as coal. Suffice it to say, you melt your ore with cheap coal as against costly coke, and further, you do it with the saving of 33 per cent. of the fuel's weight. Of course, the question that interests any one conversant with these matters is, how do you effect a saving of 80 per cent. to 90 per cent. in power, over what others have done in the same field. Apparently I do—but I don't. The truth is—we don't do the same thing.

It has been and is (with the exception of my method) the practice to melt the ore and maintain it molten, the molten mass being a path of low resistance for the passage of the current, in which reduction takes place by the hot carbon of the electrodes and the gases of carbon given off. To maintain this mass molten requires the large expenditure of energy. Instead of this my work consists in holding the ore (but a small portion at any one instant) by a powerful magnet. Only the portion held by the magnet is melted, the ore supply from above resting upon the magnetic bridge and being thereby restrained from slipping through. The poles of the magnetic circuit are also the poles of the melting circuit. Electrodes, there are none, the resistance being the ore itself, which as fast as fused is carried out of the zone of fusion and dropped, its place being taken by ore from above.

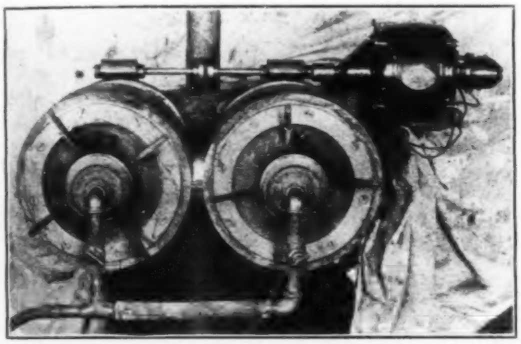


FIG. 2.—FRONT VIEW, SHOWING BRIDGE HEATED, 700 AMP., 50 VOLTS.

Preparatory to the electric furnace, the ore should be cleaned up to the highest possible point, so as to avoid the treatment of useless earthy and cinder-forming matters. Magnetic ores may be quite lean and yet pay to crush and clean. In some cases the crushing must be quite fine to produce economic results. This iron dust cannot be used in a blast furnace, but is just what the electric furnace wants, the finer the ore the more intimate the mixture of the charge may be and the more thorough the reduction.

The ore is mixed to produce the desired chemical analysis of the finished material and the required reducing material is incorporated. At the high temperature of the electric furnace the charge is fritted into a homogeneous mass, minus a large part of its oxygen, and is discharged from the furnace very hot and kept hot so that the cementation may finish the elimination of the contained oxygen. The material is then ready for melting in an open hearth furnace and is steel.

The accompanying pictures are photographs of a furnace now in operation.

A little study will show the horizontal horseshoe magnet, divided and insulated (electrically) at the bend of the magnet, the supporting post forming the pin of the hinge joint. The magnetic poles are within the bronze revolving rolls against whose surfaces the melting is done. They are water-cooled. The rolls are driven at four revolutions a minute by the small motor and the worm gears, making roughly, 16 feet of peripheral speed a minute.

THE ABUSE OF ELECTROPLATING.

By H. L. Haas, Ph.B.

Electrometallurgy has, until very recently, been wholly in the hands of unscientific men, workmen who have never given it the proper attention as a science.

Formerly very little attention was paid to the composition of a plating solution, nor what chemical changes took place in it during electrolysis. When a solution did not deposit its metal properly, the plater thought it needed a handful of this or a spoonful of that, and threw it in, not knowing whether it was soluble in the solution or not or what change was produced. And when that did not work, he thought perhaps it needed another handful or spoonful of something else, irrespective of any exact quantity or what the chemical change would be by the addition of it. And when it still did not work he was at a loss what to do further, so did the only thing possible—threw it away and started to make a new one (because he was a plater and not a scientist). But the new solution was no better than the first. And why? Because he had made it with a handful of this and a spoonful of that and an unknown quantity of something else that he had forgotten the name of (because he was a workman and not a scientist).

If he bought certain chemicals, the nature of which he did not know, or what percentage of purity, he was again in trouble when his solution did not work properly, because he had made it in a careless manner with only a workman's knowledge.

He had electric current, to use his expression, yet the solution did not deposit. He knew only that he had a current, because when he connected the positive and negative wires he obtained a spark.

The platers' voltmeter was formerly an old, rusty file, which they used to put across the two wires, making the connection and obtaining a spark. Then they knew they had electric current, but they did not know or care how much they had, because they had never measured it.

Electroplaters should know the following in order to be thoroughly conversant with their work:

First. Exactly what the depositing solution is made of.

Second. What takes place in the solution during the action of the electric current.

Third. What chemicals they are using, their properties and purity.

Fourth. The solubility of the anodes.

Fifth. How much electric current is necessary to deposit the metal properly; how many volts and ampères are employed.

Sixth. How much resistance the solution and anodes offer to this electric current.

Seventh. The distance between the cathodes and anodes, and whether it varies.

Eighth. The amount of metal that is dissolved in a given time by the action of the electric current on the anodes.

Ninth. The amount of metal that is being deposited on the cathodes.

In this manner the plater is in a position to determine at all times what is going on in his solution, and if anything is wrong can obviate the difficulty, because he knows instantly the remedy for it.

For example, as in the case of silver and gold, the best plating solution is composed of cyanide of silver or gold. Cyanogen is evolved at the anode and silver or gold, as the case may be, is deposited upon the cathode. Chemicals used for making these solutions are cyanide of potassium and chloride or nitrate of silver or gold, or cyanide of silver or gold.

It is a known fact that, when subjected to the electric current, these two metals are dissolved very rapidly at the anode. The consequence is, when plating with them, very small anodes are all that are requisite to keep the metallic strength of the solution up to the proper standard.

In the case of copper and brass, which do not dissolve in

cyanide of potassium as readily as the two former metals when subjected to the action of the electric current, a larger surface of these two metals should be employed as anodes than in the case of silver and gold.

With nickel, it is a known fact that this metal is only with great difficulty soluble in sulphate of ammonia (which is the regular solution used for nickel plating) by means of the action of the electric current, and as a consequence the largest possible surface of nickel anodes should be employed.

It has been practically demonstrated that the maximum plane surface of nickel anodes that can be placed in a tank of a given size, even when suspended on both sides of the cathodes, were not sufficiently dissolved by the action of the electric current to give the same amount of metal to the solution that was deposited upon the cathode, consequently the solution would in time become too weak in metal; therefore a larger surface of nickel must be placed in the bath, and the only manner in which this can be accomplished is by adding metal in some form to the solution. Formerly this was done by means of the addition of fresh nickel salts dissolved in the solution, which was both detrimental and expensive. Then the corrugated nickel anodes were invented, and it was practically determined that if one-third more surface of nickel was subjected to the action of the electric current in a nickel solution, the same amount of nickel would be dissolved into the solution as was deposited on the work, and as a consequence the solution remained almost constant in metallic nickel, thus obviating the addition of metal in any other form.

I advocate that all plating solutions should be made as simple as possible. By this means the plater, knowing at all times what is taking place in his solution, can readily remedy any error. But if the solution is complicated, and there are various chemicals that really have no special advantage, should the solution go wrong the plater is at a loss to know where the trouble lies, and therefore is apt to ruin his solution in trying to doctor it.

I have been endeavoring for many years to bring this up to a scientific standard, and with many gratifying results.

At the present time platers are giving more attention to the composition of their solutions. They weigh their materials; they endeavor to acquaint themselves with the action that the electric current produces on a solution; they pay more attention to the electrical contact, their different connections, the advantages of keeping them clean and free from all corrosion. They are using voltmeters and ammeters for measuring their electricity, switchboards for reducing their current to the proper and best point for the proper deposition of the metal, and I am pleased to say that the results which are now obtained in plating of the various metals are far better in every way than formerly. And I feel confident it will only be a few years when it will have reached the high standard of other sciences.

THE PHYSICAL CHARACTER OF METAL DEPOSITS.

By Prof. C. F. Burgess and Carl Hambuechen.

In the passage from a liquid to a solid condition a substance usually assumes a crystalline structure, the form of which is influenced by various factors, such as chemical composition, temperature, density, etc. Electrodeposition is the passage of metals from the state in which they exist in a solution to a solid state through the aid of the electric current. In passing an electric current through an aqueous solution of a metal salt, the metal in the solution is caused to separate out, changing its physical condition and developing properties of cohesion between metal particles thereby deposited. The amount of cohesion between metal particles after separation from the solution varies through a wide range, depending upon the various conditions of operation. Under certain circumstances, the metal may assume regular geometrical forms or crystals, and, in fact, metals are almost invariably deposited in such forms. Although to the eye a deposit may appear amorphous, under the microscope it may be shown to consist of a great number of minute crystals in juxtaposition.

The appearance and character of a growth of metal is determined to some extent by the size and shape of the crystals and the manner in which they build up. They may assume innumerable forms, all the way from spongy and almost gelatinous masses to coarse crystalline and dense structures. With suitable conditions of current, solution and metal, growths may be produced which will assume almost any of the forms of plant vegetation, to which they may perhaps be best compared. A photograph of a copper deposit might, with suitable background, be mistaken for a tree in the winter time, with trunk, branches and twigs. Various kinds of trees may also be produced in miniature with such exactness as to show the formation of buds and leaves upon them. The grasses, ferns and mosses may be produced in form in a similar manner. So much do these forms resemble plant growth that the term metallic vegetation has been applied to depositions of metals which are produced by electrolytic means.

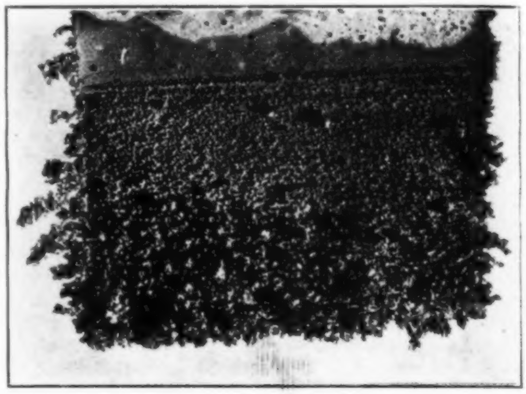


FIG. 1.—ZINC DEPOSIT.

A study of the conditions under which various forms of metallic vegetation can be cultivated is very interesting and a promising field for research, inasmuch as the exact conditions for the growth of various kinds of formation are very little understood. From the practical standpoint, the study of these growths is important, not so much as showing how they may be cultivated, but rather how they may be suppressed. It is not branches, twigs and outgrowths that the electroplater or electrorefiner wishes to obtain, but rather roots and a dense undergrowth. Knowledge as to how the conditions may be regulated so that this may be effected governs the success of many technical processes. The factors determining the forms of deposits and those which the metal depositor has in his

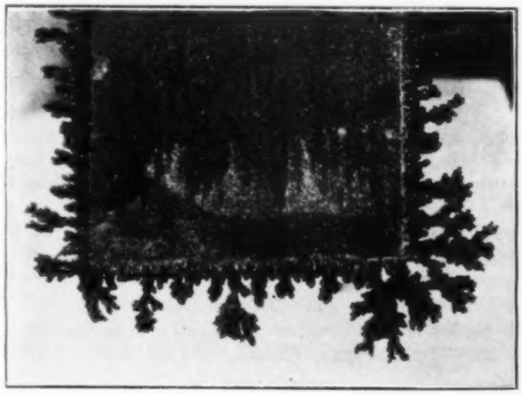


FIG. 2.—COPPER DEPOSIT.

power to regulate are the following: Chemical composition, concentration and temperature of the solution, the current density and circulation.

The accompanying illustrations are taken from photographs of metal deposits, and illustrate a few of the typical formations which are frequently obtained. Fig. 1 shows the shrub or fern-like growths of zinc. Fig. 2, the larger tree crystallization of copper. Fig. 3, a reproduction of the growth around the edge of the cathode receiving an iron deposition. Fig. 4, the appearance of crystalline lead as deposited from a lead acetate solution.

The most important factor in regulating the quality of the deposit is the composition of the solution. As is well known,

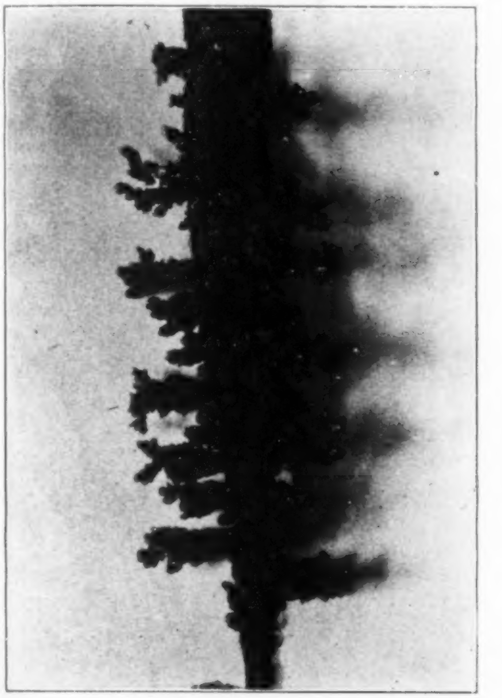


FIG. 3.—IRON DEPOSIT ON EDGE OF CATHODE.

the deposit obtained from a nitrate, sulphate, chloride or other solution of a particular metal is to a large extent characteristic of the particular solution used. The presence of certain substances added to a metal solution will also influence the kind of deposit, sometimes for the better and often for the worse. Aluminium sulphate added to a zinc sulphate solution affords a marked improvement in the quality of zinc deposit, although the aluminium sulphate itself undergoes no chemical change. A small quantity of carbon bisulphide in a silver-plating solution enables a polished coating to be obtained, whereas when omitted the surface would become rough much more quickly. A similar effect may be produced by introducing a very small amount of gelatine into a nickel-plating solution, although if the amount exceeds a certain very small quantity the coating will be rendered worthless. The importance will, therefore, be seen of not only paying attention to the chemical composition of the solution, but to its purity as well.

At the present time there seem to be few guiding principles showing what substances may be introduced to a metal solution to advantage, and what substances should be avoided. The physical character of the deposit, being so greatly influenced by the quality of the solution, seems to indicate that the solution itself has some physical structure, such as a peculiar arrangement of molecules or other physical characteristics, which determine what the character of the deposit obtained from it will be. If the solution has some cellular structure which would correspond to the crystalline structure of solids, we would have some explanation of the marked influence on the quality of deposit which the introduction of some foreign substance to the solution will exert, inasmuch as the structure of the solution itself would be influenced thereby. There seems to be some grounds for the belief that the viscosity and surface tension of a solution has some relation to the quality of the deposit, and that if we add a substance to a metal salt which will alter the above properties the quality of the deposit may be thereby influenced.

A fact that is worthy of note, and which may explain the differences in the results obtained by different experimenters, and the difficulties which have frequently been encountered in reproducing effects which have previously been obtained, was brought out in some work being carried on by Mr. C. I. Zimmerman in the electrochemical laboratory on the deposition of zinc. He found that the kind of deposit which was obtained from a zinc sulphate solution prepared by dissolving crystals of zinc sulphate in water was materially different from the deposit obtained under similar conditions of temperature, current density and content of solution, in which case, however, the solution was prepared by dissolving pure zinc in diluted sulphuric acid until it became of the same neutrality as the solution obtained by dissolving the crystals. A similar characteristic has been noted in the deposition of iron from sulphate solutions made by dissolving iron sulphate in one case and iron in sulphuric acid in another. It has further been found that the boiling of a solution and the subsequent cooling to room temperature may also materially change the character of the deposit.

The effects of concentration of solution, temperature and current density have been more carefully investigated than has the effect of the chemical and physical nature of the solution, and it is not the purpose to deal here with those factors.

In the deposition of metals for ornamental and protective purposes it is not only important that the metal deposited shall be firm and uniform throughout the entire surface, and that the particles of metal shall have considerable coherence among

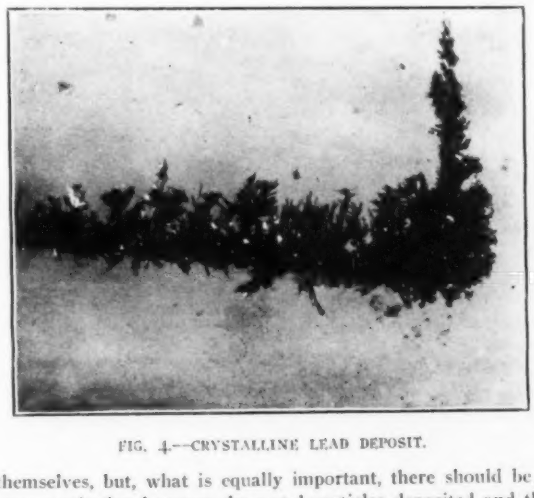


FIG. 4.—CRYSTALLINE LEAD DEPOSIT.

themselves, but, what is equally important, there should be a strong cohesion between the metal particles deposited and the metal surfaces upon which they are deposited. This, as is well known, depends most largely upon the surface cleanliness, which influences the intensity with which metals deposited upon the same will adhere. It also depends to a certain extent upon the metal receiving the deposit and the metal being liberated.

The fact, as shown in the preparation of metal alloys, that certain metals have greater affinity for each other than have certain other combinations, seems to make itself evident in the cohesion or attraction between the metal which is electrodeposited and the metal receiving it. It is held by some that

for the best adherence there should be a true alloying at the surface separating the two metals, and this appears to be borne out by microscopic examination of certain deposits. Zinc may form a very adherent coating on copper, due to the fact that the zinc alloys with the copper surface to a certain extent, and the poorer adhesion to iron may possibly be accounted for by a lesser affinity between two metals or, in other words, a lesser tendency to alloy. Gold will alloy very readily with zinc at ordinary temperatures, as shown by the very striking observation that a gold coating applied to a zinc surface will in a few days entirely disappear, being absorbed by the zinc.

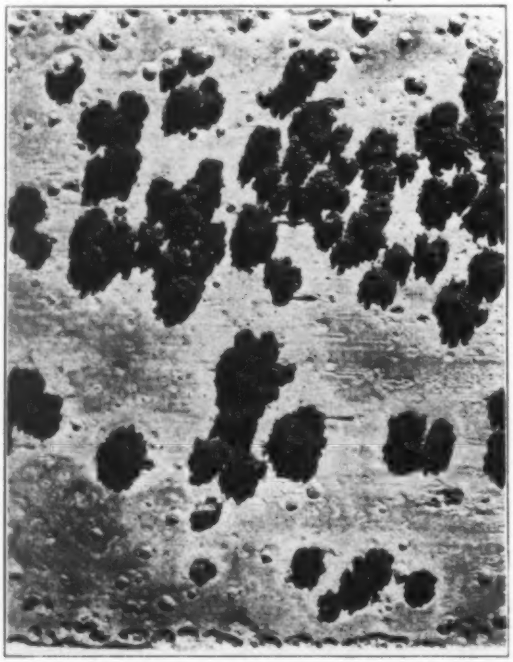


FIG. 5.—MOSS-LIKE GROWTHS ON ZINC CATHODES.

This alloying phenomenon, however, cannot be held as a universal one, for there are certain contradictory facts which must be taken into account. In many cases, one of which is the deposition of nickel on iron, there is no evidence for claiming that there is an alloying of the two metals, although a good adherent coating may be obtained. Further, if there is a tendency to alloy, it might naturally follow that the alloying would proceed indefinitely, and that the degree of adherence of the coating would increase with time. It is a matter of common observation, however, that many electrodeposited coatings become less adherent with time.

In fact, the theory of the alloying of the surface is not necessary in explaining the tenacity with which one metal will adhere to another, but a more satisfactory explanation is probably found in the direct cohesion which is established when solid particles are brought into intimate contact. Copper may be deposited in such a way that a cohesion between the copper particles themselves may be so great as to resist a force of 25 tons per square inch or over to separate them. If a copper particle is brought into intimate contact with an iron particle, a similar cohesion, though perhaps less in degree, will result. On this basis, therefore, it is desirable that in the electroplating processes the deposited metal should be brought into as intimate contact with the surface receiving the deposit as is possible. The adherence of a coating, as a consequence, will depend upon the amount of surface which is to be brought into contact.

It is well known that a surface which is somewhat rough will receive a more adherent coating than will a polished surface, and this is undoubtedly due largely to the greater amount of actual surface per superficial area which is brought into contact. Upon this supposition of the desirability of intimate contact of metal surfaces, the influence of the electrolyte on the adherence of a deposit may be explained. A surface which has had the proper physical treatment to prepare it for receiving a coating may have the appearance of being perfectly polished, but an examination by the microscope will reveal the fact that the surface is made up of minute particles with crevices between them. If, on immersing this surface into a plating solution, the solution penetrates into such crevices by passage of electric current, the metal will be deposited upon every point exposed to the solution. If, on the other hand, the solution is of such a nature that it will not go into these minute crevices, in which case the air or other insulating material will be retained therein, it is quite natural to suppose that it will be only the more elevated points which are in contact with the electrolyte. These points will receive the deposit, which will grow sidewise from these projections until the cavities are bridged over and the entire surface has the appearance of being coated. In this case it will be evident that the adherence of the coating will not be as great as it will be where the metal goes into the depressions.

As is well known, some solutions will "wet" a surface much more readily than will others, and in using a solution from which an adherent coating is to be obtained it is desired that the solution shall have the property of most thoroughly wetting the entire surface. Or, in other words, the electrolyte should consist of a solution in which there is a large mutual molecular attraction between the liquid and the metal surface. This property can be imparted to various solutions of metallic salts by the addition of certain other soluble substances, and it is for this reason that such additions are frequently practiced. It is easily shown that a coating of copper obtained by immersing aluminium in a copper chloride solution is very non-adherent, and may be readily brushed off; but that if an alcoholic solution of the same copper be employed, the coating is much more firmly adherent. This may, therefore, be explained on the supposition heretofore advanced that alcohol causes the copper solution to come into more intimate contact with all parts of the aluminium surface. In this connection, an investigation of the relation between the surface tension of solutions and various metallic surfaces upon the adherence of the coatings obtained would undoubtedly lead to some interesting results, and might establish guiding principles in the design of plating solutions.

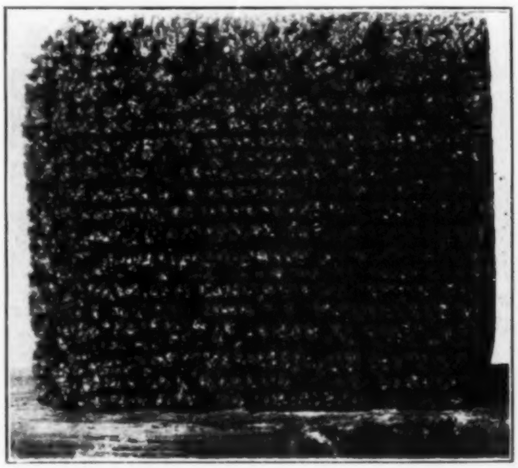


FIG. 6.—ROUGHENING OF IRON DEPOSIT.

The peculiar characteristic of all deposited coatings is that, no matter how dense, coherent and smooth the metal surface deposited may be, the cohesion and smoothness decrease with

time, and the surface eventually becomes rough. This is a serious limitation where thick deposits are desired, as in the electrolytic recovery and refining of metals.

Fig. 5 illustrates the appearance of moss-like growths on zinc cathodes. Fig. 6 illustrates a roughening of an iron deposition, and a phenomenon which frequently is observed is here shown, namely, the grooving or furrow characteristic. These grooves, which are almost always obtained in a vertical position, are due to the fact that the solution in the immediate neighborhood of the cathode, becoming depleted in metal, decreases in density and rises to the surface of the tank. The rising solution is, by the formation of small projections near the bottom of the anode, split up into columns of dilute solution, separated by columns of more dense solution. The electric current, finding a more ready path through the dense solution, deposits the metal more readily therefrom, and thus starts the ridges, after which the action becomes more pronounced. The remedy for this defect will be at once evident,

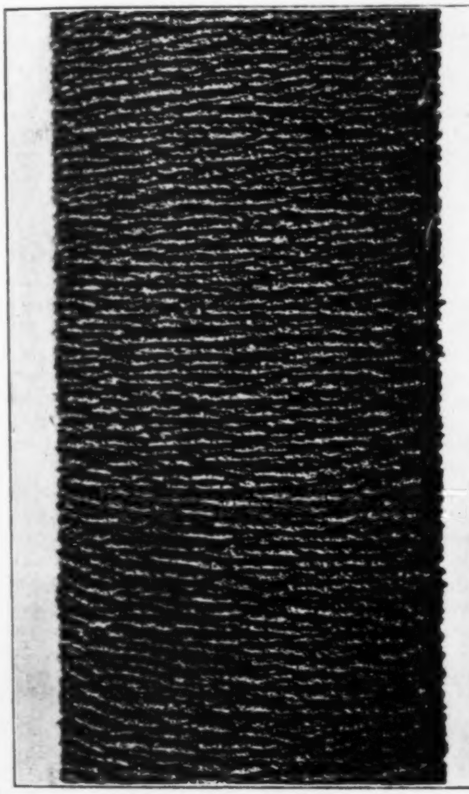


FIG. 7.—HORIZONTAL GROOVING, OBTAINED BY ROTATING A CYLINDRICAL CATHODE AROUND A VERTICAL AXIS, ZINC DEPOSIT.

for, if the solution be agitated by stirring or other means, it may be prevented. This vertical position of the grooves is due to the fact that it has the same direction as the flow of the solution. An interesting example of horizontal grooving is illustrated in Fig. 7, where a cylindrical cathode was rotated around a vertical axis while receiving a deposit of zinc.

Fig. 8 illustrates another effect which is frequently developed in electrodeposition, namely, the pitting or perforation of the metal. Perforations may be caused by the presence of insulating particles on the surface receiving the deposit by the deposition of particles of foreign substances which may be floating around in the solution, or by the liberation of bubbles of gas, which may adhere to the cathode. This defect is most commonly caused by the liberation of gaseous products, and the remedy is the choice of a solution from which such gas will not be liberated or by circulation or agitation of the solution.

These bubbles of gas, usually consisting of hydrogen, which may adhere to the cathode surface in sizes varying from most minute dimensions to one-eighth of an inch in diameter, insulate the surface at such points, and the metal may be built up around them, even completely inclosing them. This results in a porosity and inclusion of gas frequently found in deposited metals. Fig. 8 illustrates such pitting, and the wavy form which the metal takes around the lower portion of some of

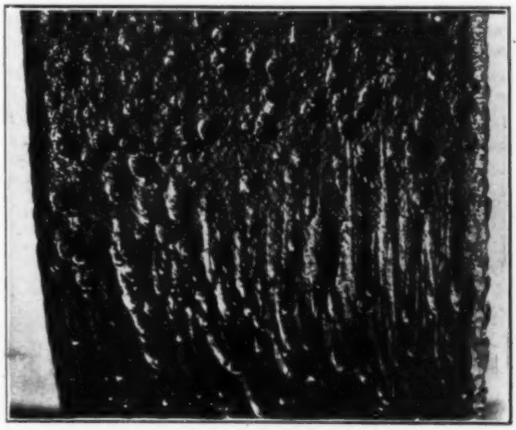


FIG. 8.—PERFORATION.

these cavities indicates the way the solution divides and flows around the obstructing gas bubbles.

Another peculiar property of electrolytic deposition, and one which makes itself particularly manifest in the separation of nickel, is the distortions in shape which certain deposits take after the deposition has proceeded to a certain thickness, or upon subsequent heating or other treatment of the metals. This is due to the strains which are set up during the process of deposition from the solution. It is claimed that nickel

FIG. 9.—NICKEL COATING, PEELING OFF.

deposited on a thermometer bulb will tend to contract with force sufficient to compress the glass and cause the mercury column to rise. This property becomes prominent in nickel plating where the coating is allowed to exceed a given thickness. These strains are such as to cause the nickel to tear away from the surface being plated, as is illustrated in Fig. 9.

LABORATORY OF APPLIED ELECTROCHEMISTRY,
University of Wisconsin.

HISTORY AND PRESENT DEVELOPMENT OF ELECTROLYTIC NICKEL REFINING.

BY TITUS ULKE.

Probably the earliest attempt to electrolytically separate nickel from its alloys or matte, in any continuous or semi-continuous process of refining such substances, was made by Emil André, who obtained a German patent, No. 6,048, of November 1st, in 1877. André's process consists, briefly, in suspending nickel-copper bearing material, cast into plates, as anodes in an acid solution, and electrolytically depositing out most of the copper on cathode plates of sheet copper, and finally the balance of the copper on such plates, with carbon anodes put in place of the nickel-copper anodes, this deposition occurring necessarily under varying and, therefore, in my opinion, commercially impracticable chemical and electrical conditions, then withdrawing the entire solution thus freed from copper, and recovering the nickel from same, after removal of any iron it contains and making it ammoniacal, by electrodeposition of the nickel on suitable cathodes and with (evidently unsuitable) anodes of ordinary iron or zinc. This process was tried in Germany and abandoned.

Not daunted by this and other failures, patents were obtained by Messrs. Basse & Selve, Ricketts, Hoepfner, Frasch, Browne, Ulke and others for the electrolytic separation of nickel or nickel salts from combinations of nickel with other metals or metalloids, and in some cases from ore, and works in Germany, Wales, Canada and the United States were erected, using processes based on several of these patents. In the following pages I shall now describe these interesting refining plants, to which visitors are almost invariably denied admission, as fully as the rather meagre data at my command will permit, treating the Vivian, Balbach, Cleveland, Hamilton and Papenburg Electrolytic Nickel Works in turn and ending with a discussion of the proposed copper and nickel refinery at Sault Ste. Marie.

I. VIVIAN'S ELECTROLYTIC NICKEL-COPPER SEPARATING WORKS.

In 1892, according to Mr. A. F. Weightman, who kindly furnished me with the following data, H. H. Vivian & Co., of Swansea, Wales, started a new electrolytic copper refinery in connection with their nickel, cobalt and copper works, and introduced the recovery of nickel as a special feature of this plant.

In treating ores from Sudbury, Canada, containing nickel, cobalt and copper, by the "wet" process, at a certain stage of the latter large quantities of "residues" were obtained, which were melted down into anodes for electrolytic separation. These anode plates of nickel-copper alloy were placed in lead-lined depositing tanks, containing an acidified solution of copper sulphate, opposite copper cathodes. On passing an electric current, copper was alone deposited, and the solution therefore became richer in nickel and poorer in copper, until it was eventually withdrawn and treated especially for the recovery of the nickel.

The plant erected in Swansea was designed for the treatment of 10 tons of copper and nickel per week, but it never reached its full capacity, for reasons discussed later.

The anodes contained about 60 per cent. Cu and 40 per cent. Ni. As each pair of regular anodes and cathodes had one or two intermediate plates suspended between them, in series circuit, the system of refining used was based on a combined multiple and series arrangement of electrodes.

Forty tanks, loaded with plates thus arranged, and worked at a current density of 10 ampères per square foot, were installed, together with 10 tanks, known as "finishing" tanks, which were provided with lead anodes for the purpose of removing the last traces of copper from the solution.

The main tanks were arranged in pairs and each pair was supplied with solution independently. It was the company's aim to obtain good reguline copper in these tanks and to run off a liquor containing nickel and copper in the proportion of 9 to 1 into the finishing tanks, which would yield non-reguline copper. Experience soon showed, however, that this object could not then be attained, as the copper deposited in the main tanks was of a more or less non-reguline character and frequently "treed across" to the anode or to anode side of the "intermediate" plates and short-circuited the tanks. These tanks had to be repeatedly cleaned out on this account, and constantly required one man's time testing them with some form of voltmeter for short circuits. Whenever a tank short-circuited, the amount of copper in the solution escaping deposition in a given time and run into the finishing tanks, would quickly overtax the capacity of the latter. In the finishing tanks, as had been expected, the copper came down as a black, bulky powder, which accumulated in the bottom of the tanks rapidly and soon short-circuited the cells. In consequence it became necessary to clean them out every day, until a scheme to be described presently was adopted. The difficulty with short-circuiting was so great that the actual output of the refinery was always much below its designed capacity, and this defect was further exaggerated by trouble with the dynamos. In those days British dynamo manufacturers were only accustomed to making machines for lighting purposes, in which the generator was only taxed to its full capacity for a few hours during the day, and ran the rest of the time on a light load. The result was that the machine supplied to the above works was quite inadequate to maintain a full load for weeks at a stretch and gave constant trouble during early stages, although more or less satisfactorily remedied subsequently.

The trouble from short-circuiting was considerably lessened by the following scheme introduced by Mr. Weightman in 1893, and recently patented, I believe, by Dr. Keith. As the solution in the finishing tanks got weaker and weaker in copper, the current density was continuously decreased, and this resulted in obtaining a more reguline deposit of copper and also in lessening the proportion of the refinery current wasted in evolving hydrogen, which occurred freely by the old method. Even with these improvements, the liquor could seldom be obtained sufficiently free from copper, *i. e.*, with not over 0.1 per cent. Cu, which was the maximum allowable. Consequently the last traces of copper had to be "gassed down" with hydrogen sulphide, involving trouble and expense, and defeating largely the object of the process. Short-circuiting was also checked by casting the anodes somewhat smaller than the cathode sheets. This disposition not only removed the anode from that part of the system where "treeing" was the worst, namely, at the edges of the sheets, but it also checked the tendency to tree for the following reason: The distance the electric current had to travel from the edge of the anode to the edge of the cathode, since it had to take an oblique path, was greater than the distance between any other opposed portion of the electrodes, and consequently the resistance was greater. Therefore the current density at the edges was less than on any other part of the cathodes and the "treeing" was consequently checked.

The method adopted for stripping the cathode sheets from the cathode pattern plates consisted in varnishing the latter with a weak shellac varnish containing about 1 pound of shellac to 1 gallon of alcohol, which gave a coating sufficiently thick to prevent the copper deposited over it from sticking, and at the same time not thick enough to insulate the cathode from the passage of the current. The edges were dipped in "Brunswick black," and the pattern plates thus prepared, were hung in the cathode starting tanks to receive their copper deposits and form sheets, which were then easily detachable from their pattern plates.

An ordinary electric bell was found very convenient for testing the voltage of the cells. This bell was specially wound so as to ring at its ordinary loudness when the cells were at the correct voltage. If the bell rang more or less loudly it was a sign of either dirty contacts or short-circuiting in the particular cell under test. It was astonishing how exactly a man could tell the condition of a cell with this simple instru-

ment, and how much more it appealed to the average workmen than a delicately pivoted and expensive voltmeter.

In carrying out the above separating process, a very large amount of anode scrap was produced, which was expensive and troublesome to remelt, because of the high melting point of the Cu-Ni; alloy. The amount was diminished by casting the anodes about ⅛ inch thicker at the top than the bottom (accomplished by setting the molds a little out of the level), and thus checking the tendency for the anodes to be eaten away at or near the surface of the electrolyte. The anodes were cast in closed molds and weighed about 80 to 90 pounds apiece. It was considered inadvisable to exceed this weight as most of the work in the cell room (in common with most English refineries) was done by manual labor, and any weight over 80 to 90 pounds was inconvenient to handle.

The copper-sulphate electrolyte was obtained by dissolving roasted matte by well-known methods and adding an excess of about 10 per cent. free sulphuric acid. The purified nickel-sulphate liquor from the cells, practically a saturated solution, was run off and boiled down until the anhydrous nickel sulphate separated out. This was then roasted to oxide and reduced to metal by carbon, although it was intended to eventually recover the nickel in a much purer state by electrodeposition.

Small quantities of platinum were obtained in the anode slimes, but never in sufficient amount to be of appreciable account on the cost sheet.

The success of the above-described process was not considered sufficient to warrant its permanent establishment, and in 1894 the refinery was therefore closed.

II. Balbach Electrolytic Nickel Refinery.

The largest and most successful electrolytic nickel refinery up to date appears to have been the one at the Balbach Works, Newark, N. J., erected in 1894 and operated until 1900, under the superintendence of Mr. F. A. Thum, who is believed to have originated the process employed there. Although this process has been jealously guarded as a secret by the Balbach company, and the exact conditions under which nickel refining may be successfully carried out practically were independently investigated and first published by others, the credit of being the pioneers in the commercial electrolytic refining of nickel as well as of copper in America undoubtedly belongs to the Balbach firm.

The analysis and mechanical tests of samples of nickel cathode made at the above works and seen by the writer indicated that the cathodes were remarkably pure and strong. The total absence of such elements as carbon, silicon and sulphur in the electrolytic product was accompanied by such good physical properties, particularly in the way of increased ductility, malleability and tensile strength, as to make it far superior in these respects to any fire-refined nickel I have ever tested. The only impurity, besides cobalt, found in the Balbach nickel was iron, and this only up to 0.25 per cent., which is certainly remarkable, in view of the close electrochemical relationship existing between these elements.

Although I had no occasion to see the Balbach plant in actual operation or to get any official information as to the composition of the electrolyte employed, I am convinced that the metal was produced by a process quite like that proposed by Prof. Foerster about three years ago in a communication published in the *Zeitschrift für Elektrochemie*. In this process solid plates of pure metal to any required thickness may be deposited from neutral sulphate solutions heated to from 50° to 60° C.

The Balbach nickel cathodes had about the same dimensions and shape as the copper cathodes from the company's multiple system copper refining plant, showing that the same system and apparatus were probably applied in the refining of both metals.

The crude nickel anodes, assaying from 94 to 97 per cent. Ni, were furnished by the Orford Copper Co., of Constable Hook, N. J., and were reduced from their nickel oxide in a reverberatory furnace. The anode scrap and residues from the electrolytic process were returned to the Orford Works and put back into the nickel anode furnaces, to be returned again as anode to the Balbach Works and reworked electrolytically until the residues were at last rich enough in precious metals to make separate refining and parting profitable

The above outlined process is not now in use there, as the Orford Co., upon whose nickel material the Balbach Co. were dependent, has ceased shipping crude nickel in the shape of anodes to the Balbach refinery, and is itself producing fairly good metallic nickel, averaging about 99.21 per cent. Ni; 0.66 per cent. C, Si, S, etc., and 0.13 per cent. Cu, by reduction of nickel oxide with carbon. This Orford nickel, however, being contaminated with carbon, silicon and sulphur, is neither as pure, nor as strong as good electro nickel obtained by the above process.

The Balbach nickel refinery was started in 1894, but its operation was discontinued about three years ago for reasons unknown to me, although I surmise that the large production of scrap from the imperfectly smelted and very brittle anodes was partly accountable for its closing down. The taking out of a patent by Mr. F. A. Thum for the electrolytic refining of nickel from metallic powder or granules, such as may easily be reduced from nickel oxide, to obviate the use of cast anodes, seems to point in that direction, and the same object of diminishing trouble with the anodes evidently also underlies the suggestion made by Mr. William Thum, also of Newark, to use slabs of crude nickel as electrodes in a series system, wherein the nickel deposited on the cathode side would make a staunch backing for the crumbling crude nickel of the anode side and thus obviate the difficult casting of anode suspension and contact lugs. It is claimed that electrolytic nickel can be produced from Orford anodes in this way at a cost of less than 1 cent per pound.

Besides metallic nickel, the Balbach Smelting Co. have been a heavy producer of nickel plater's salts. Such salts have been profitably recovered, for the last twelve years, as by-products in processes for the regeneration of its foul electrolytes from the company's copper refinery, the small quantities of nickel contained in the blister copper treated being all retained in the acid electrolyte and, of course, concentrating therein.

The Balbach method of recovering the nickel sulphate consists chiefly in repeated fractional crystallizations and a final removal of the remaining copper by electrolysis.

III. Cleveland Nickel and Copper Refinery.

This refinery developed from an experimental electrolytic plant started six or more years ago in the Brooklyn suburb of Cleveland, Ohio, by the Canadian Copper Co.

The commercial plant, operating under a Canadian patent of Mr. David H. Browne, No. 74,401 of January 14, 1902, reissue of No. 69,729 of December 21, 1900, in 1902 began to produce, and turned out from 8 to 15 tons of electrolytic nickel per month, but closed down several months ago, I presume, temporarily.

Mr. Browne's electrolytic process consists of the following steps: Anodes of copper-nickel alloy and cathodes of pure copper are suspended in a solution of copper-nickel chlorides which is continuously regenerated by passing it through a tower filled with Bessemerized matte or alloy to be treated, in contact with salt solution and chlorine gas evolved from the nickel precipitating process. When the electrolyte is rich in nickel, and the copper nearly all deposited on the copper cathode, the remaining copper is probably gassed down with hydrogen sulphide and removed, the iron precipitated with ammonia and filtered off, and the hot neutral nickel chloride solution remaining, electrolyzed in contact with carbon anodes

in a water-sealed compartment (See Fig. 1.), and pure sheet nickel cathodes. The chlorine evolved from the anode compartment is conveyed to the regenerating tower to assist in

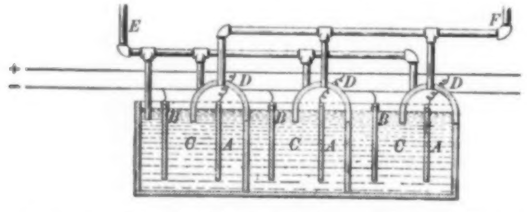


FIG. 1.—BROWNE'S ELECTROLYTIC PROCESS FOR THE ELECTROLYTIC SEPARATION OF NICKEL AND COPPER.

dissolving additional nickel and copper from the material that is treated. It is rumored that the erection of larger works, operating as above outlined, at a more suitable location, is contemplated.

IV. Hamilton Nickel-Copper Refinery.

This plant was built about three years ago at Hamilton, Ontario, and consists of a frame tank house, about 40 feet wide and 100 feet long, containing, it is reported, about 40 depositing tanks, laboratory, supply tanks, etc., and storehouses. It was originally built to treat Sudbury ore by the Hoepfner process, but was remodeled later to accommodate the Frasch process and apparatus.

As described in the *Engineering and Mining Journal* of September, 8, 1900, and applied to copper-nickel matte, Frasch's process consists essentially "in the electrolysis of a brine solution, so as to produce caustic soda solution in the cathode section of a divided electrolytic tank, and chlorine in the anode section, in which is placed the nickel-copper matte, the metals in the latter being dissolved and forming chlorides.

"The copper in the solution thus obtained is recovered by electro-deposition, the nickel being separated from the cobalt, iron, and the remaining traces of copper as a double salt of nickel and ammonia, while the caustic alkali is recovered from the solution withdrawn from the cathode section as a by-product. The matte, coarsely crushed, is charged directly on a layer of carbonaceous material in the anode section of the tank, and is covered by a thin layer of sand, which is said to make a very satisfactory diaphragm for the separation of the resultant solutions of caustic soda and the chlorides of the metals. The tank is now filled with brine which is then electrolyzed, and the metallic solution obtained in the anode section and the alkaline solution in the cathode section are periodically displaced by fresh salt solution.

"When it is decided that the nickel-copper matte on the bottom of the tank has received sufficient treatment to require removal of the solid residue, the upper layer of sand is taken out and washed for re-use, and the leached or partly leached material removed."

Hoepfner's and Frasch's processes were both tried within the last two or three years, on a small commercial scale in the Hamilton refinery, but neither of them attained practical prominence. The plant owned by the Hamilton Nickel Co. has at present closed down.

V. Papenburg Nickel-Copper Refinery.

The Papenburg electrolytic works, belonging to the Allgemeine Elektro-Metallurgische Gesellschaft at Papenburg an der Ems, Germany, are said to be producing a small output of copper and nickel, according to a modified Hoepfner process, using a chloride solution. It is stated that the capacity of the works is about 1 ton of refined copper daily, and the same quantity of electro nickel, although the actual output is certainly considerably less than this amount.

The process is applied particularly to ores and matte, these being leached with a cupric chloride solution, so as to dissolve their copper, lead, nickel and silver contents, and simultaneously reduce the cupric salt to the cuprous state. After purification and being freed from silver, the solution is passed into electrolytic cells with carbon anodes and copper cathodes. Chlorine is liberated at the anodes and utilized, and the cupric and nickelic solution remaining after electrolysis is withdrawn, freed from copper, its nickel contents recovered electrolytically, and the remaining solution re-used in leaching a fresh charge of ore or matte. Very recent reports indicate that the Papenburg concern has not yet achieved commercially successful results, that for all practical purposes Hoepfner's original process has been abandoned and that the entire plant is being remodeled.

VI. Proposed Sault Ste. Marie Copper and Nickel Refinery.

The Consolidated Lake Superior Co. propose the erection of a large copper and nickel smelting and refining works at Sault Ste. Marie, either on the Michigan or on the Algoma side. Plans and estimates have been prepared for a plant with a daily productive capacity of 75 tons of fine copper, 7.5 tons of fine nickel and for refining the precious metals contained in the material to be treated, according to my improved process and plant. The works are designed especially for treating anodes of crude nickeliferous copper, averaging, say, 88 per cent. Cu, 8.8 per cent. Ni, and, say, 20 ozs. Ag. per ton. These nickeliferous anodes may be secured by adding a certain tonnage of Sudbury matte to at least double this quantity of Lake "mineral," slagging off the iron silicate, removing the sulphur, refining up to the desired point and finally casting the product into anodes. I would recommend the employment of Mr. Thum's electrode

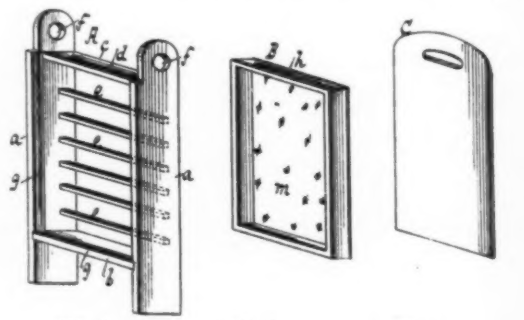
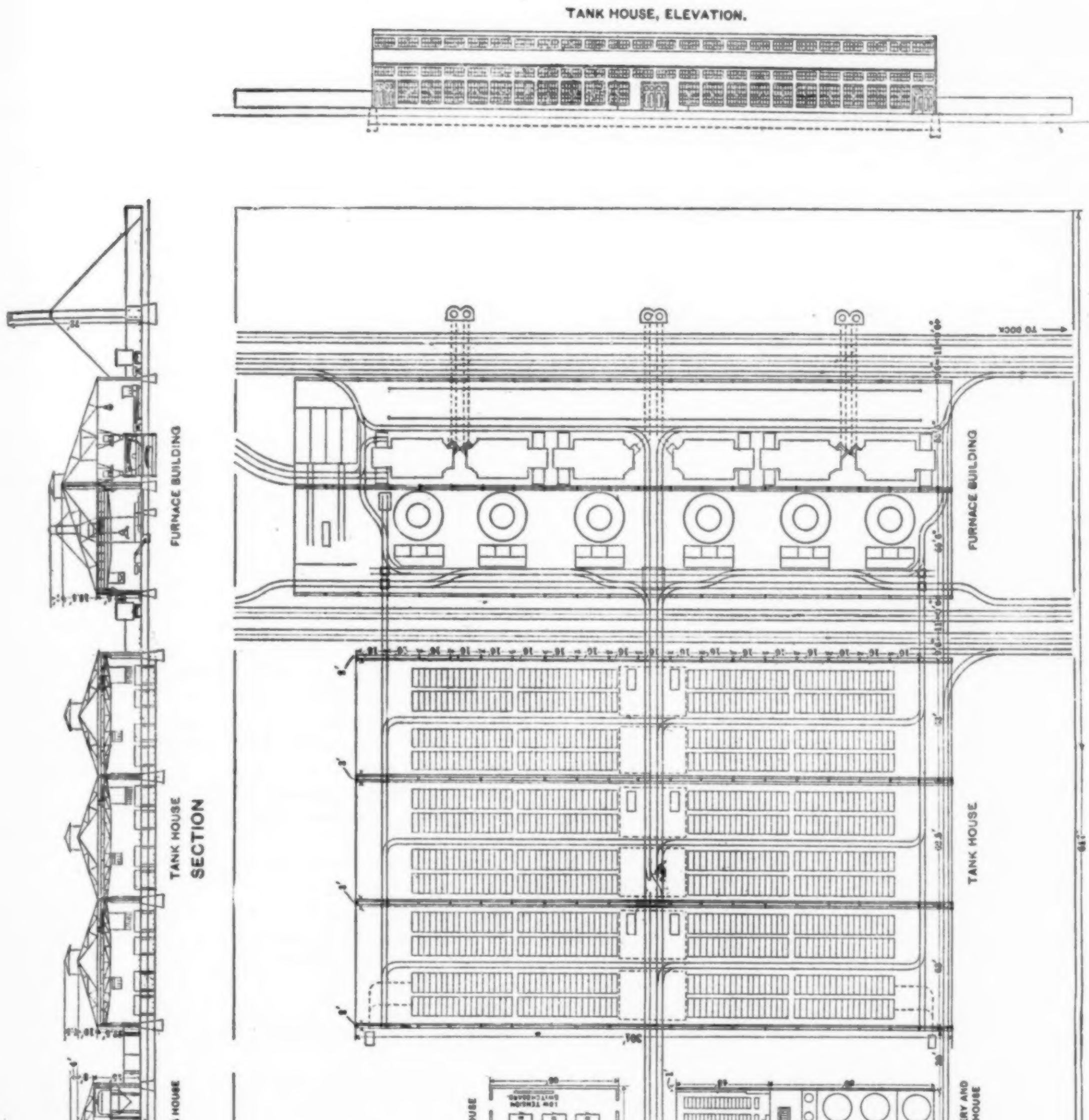


FIG. 1. FIG. 2. FIG. 3.
THUM'S ELECTROLYTIC APPARATUS.

frame, described later, in connection with my improved process for the separation and electro-deposition of nickel. This combination method would then embody the reduction of the nickel sulphate obtained in the second stage of my process to the granular, semi-metallic, or "reduced black-oxide" state, and the use of this material instead of lead, as an anode. The reduction of nickel sulphate or oxide with carbon to granular nickel takes place at a low temperature, while reduction and fusion to a *solid* nickel anode requires a high temperature and is therefore much more expensive than the process advocated.

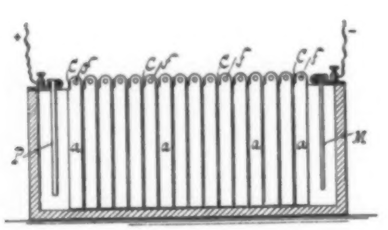
The neutrality of the electrolyte must in every case be carefully maintained, for if it is not kept constantly neutral or approximately so, and is allowed to change from an acid to an alkaline reaction or *vice versa* deposition, the electro-depositing nickel is apt to peel off and cause trouble.

The apparatus for depositing nickel described in Mr. F. A. Thum's U. S. patent No. 614,633 of November 22, 1898, as applied to nickel refining, consists essentially of a non-conducting frame A and B (see Figs. 1, 2 and 4), adapted to hold the finely powdered or granular nickeliferous material to be refined, said frame being closed at the side facing the positive conductor by a removable plate of nickel or a greased sheet of copper, and at the opposite side by a diaphragm of muslin or other suitable material. A number of such frames or elements are assembled in an electrolytic tank and arranged according



DESIGN OF PROPOSED COPPER AND NICKEL REFINERY.

to the series process (see Fig. 5), the positive current being conducted to the material to be refined, which serves as an anode, of the first element of the series, and the negative current taken away from the cathode plate or sheet of the last element, without the intervention of any intermediate conductors excepting the elements themselves. At the top of the frame is a charging opening for supplying the anode material. In detail, the frame A is formed of side pieces *aa*, bottom *b* with grooves *g*, top *c* with opening *d* and cross bars *ee*, while B is provided with an opening *h* at the top and is closed at the outer end by a diaphragm of muslin or other suitable material *m*. Frame B is inserted into the frame A, so that the diaphragm *m* is supported by the cross bars *ee* and the opening *h* is beneath the opening *d*. The element is completed, finally,



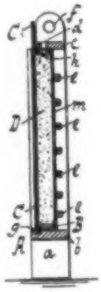


FIG. 5. FIG. 4.

THUM'S ELECTROLYTIC APPARATUS.

by a plate C of metal, such as nickel or copper, which is slightly greased and inserted into the grooves *g*, and serves as a receiver for the deposited electrolytic nickel.

When a suitable electric current is passed through the tank, filled as it is with a hot neutral solution of nickel sulphate and the electrodes as described, the anode material is dissolved on the diaphragm side and the nickel is deposited on the opposite cathode plate. As soon as the deposit has reached a sufficient thickness, it is removed and melted into ingots, or utilized, as I prefer, without melting, as the latter process is apt to introduce injurious impurities into the nickel.

Whenever there is a settlement of the material in the casing, fresh material may be charged through the openings *d* and *h*. From time to time the elements are in rotation removed from the tank, the deposits stripped from the plates C, the residue within the casing emptied, and the casing refilled.

CONCLUSION.

In the processes for the electro-deposition of nickel with insoluble anodes no very recent progress has been shown. When the metal is recovered on a large scale by the aid of soluble anodes, the electrolyte is kept constantly at a predetermined degree of saturation and at the point of neutrality, on which condition largely depends the nature of the deposit and the commercial success of the process. When insoluble anodes are used in refining nickel, however, an equivalent of free acid is left in the electrolyte for every equivalent of metal deposited, and in consequence the nickel deposit is apt to deteriorate, the chemical and electrical conditions of the bath are changed, polarization ensues and the resistance of the electrolyte increases. This, of course, means that the voltage and power required must be increased proportionately, and the cost of refining with insoluble anodes may thus become next to prohibitory, as compared with a similar process using soluble anodes. These and other difficulties have been the chief reasons why our electrochemists, instead of making pure metallic nickel by electrodeposition, preferred to work the nickel solutions into marketable sulphates, double sulphates and chlorides, which have had a ready sale until recently, but which now seem likely to become a drug on the market, just as copper-sulphate was before the adoption of electrolytic refining methods.

Permit me to say, in closing, that if any of the above-made suggestions will aid in improving the technical practice and commercial success of my co-workers in this interesting and fertile field of electrochemical work, the object of this paper will have been fully attained.

NOTES ON PHYSICAL CHARACTERISTICS OF ELECTRODEPOSITED METALS.

BY WOOLSEY MCA. JOHNSON.

This subject has never been adequately treated in any book on electrochemistry, either theoretical or practical. We find in the literature a mass of experimental evidence, but no attempt has been made to collect it and to classify it. Consequently the explanations of the varied phenomenon are always of a special nature.

In the limits of this short article it is impossible to give any general scheme, but it was thought that an investigation of why in one case the deposit is good and in another case the deposit is poor will help others to systematize our knowledge and tell us the reason for the facts as we know them.

One of the first things observed in studying this question is that in electroplating "double salts" are often used, and usually with excellent results.

The modern theory of electrolytic dissociation has developed some remarkable facts about these double salts, or, as it calls the resultants of them, "complex ions." We know, for example, that it is possible to reverse a Daniell cell by simply adding a strong solution of KCN to the catholyte; that this will give a steady discharge of a considerable current, with the copper dissolving and the zinc being precipitated.

By Nernst's equation we have

$$E = e_1 - e_2 = 0.058 \log. \frac{Pzn}{pzn} - 0.058 \log. \frac{Pcu}{pcu}$$

neglecting the small e. m. f. at the contact of the solutions.

Now, when we add KCN to catholyte, we do not affect Pzn or pzn or Pcu, but we reduce Pcu to a small value. In other words, we have decreased the ionic pressure of copper to an amount so small that its own solution pressure is sufficient to push the copper ions continually into solution. Copper hydrate is, for analytical purposes, considered insoluble, but the solution pressure of $Cu(OH)_2$ with regard to the copper ions is large compared to that of the potassium copper-cyanide that is formed.

Similarly, we find that in a "concentration cell" that reagent which produces a chemical action in precipitating a dissolved salt or in dissolving a precipitate gives a higher e. m. f. against the standard electrode.

To be concrete, the cell

$Ag|AgNO_3$ 0.1n$|AgCl$ n$KCl|Ag$ gave 0. 54 volt.
$Ag|AgNO_3$ 0.1n$|AgNO_3$ n$NH_4OH|Ag$ gave 0.54 volt.
$Ag|AgNO_3$ 0.1n$|AgBr$ n$KBr|Ag$ gave 0.64 volt.
$Ag|AgNO_3$ 0.1n$|AgNO_3$ $Na_2S_2O_3|Ag$ gave 0.84 volt.
$Ag|AgNO_3$ 0.1n$|AgI$ $KI|Ag$ gave 0.91 volt.
$Ag|AgNO_3$ 0.1n$|AgNO_3$ $KCN|Ag$ gave 1.31 volt.
$Ag|AgNO_3$ 0.1n$|AgNO_3$ $Na_2S|Ag$ gave 1.36 volt.

We can see that each reagent in the electrochemical series produces a chemical action on the compound just below it. For instance, AgCl is soluble in NH_4OH, while AgBr is precipitated by the action of KBr on the soluble ammoniacal silver salt. The same is seen through the series $Na_2S_2O_3$, KI, KCN, Na_2S. His knowledge throws a Nernst light on the subject. We find in the ionic theory of concentration cells a satisfactory explanation for the perfect correspondence between chemical behavior and the electrochemical quantity, e. m. f. against a standard electrode. The same correspondence is found true in most concentration cells measured. For further particulars, the reader is referred to Nernst's classical researches on concentration cells, in the *Zeit. f. Phys. Chemie*, 1889, or to Le Blanc's "Elements of Electrochemistry" (translated by W. R. Whitney), p. 178.

It is therefore quite easy to understand why NH_4OH dissolves AgCl, etc. It is that a double salt is formed by the two,

which has such a small pressure of silver ions that the reaction proceeds until equilibrium is reached. Looked at broadly, it is little different from the rising of heated air or the flowing of water down-hill. All three actions consist in matter flowing from high pressure to low pressure. The difference lies in us. Water pressure and air pressure are familiar to our minds, but an ion pressure is a new conception.

As is well known, these double salts are found useful to the electroplater. We need only instance the nickel bath of double nickel ammonium sulphate and the silver bath of the soluble potassium silver-cyanide. (In electroanalysis Professor Classen has made use of the double ammonium oxalates, etc.)

The value of these double salts is connected in several ways with the formation of complex ions. In the first place, they render necessary a high voltage. Take silver plating, for example. If a solution of silver nitrate were used, we could deposit silver at a very low "electrode voltage." By using the solution of $KAg(CN)_2$, we use a voltage higher by 1.20 volts. The ions are hurled out of the solution under great pressure. The following analogy illustrates this point. To be a bit slangy, we will consider a boy throwing snow at the shingled side of a house. If he tosses it gently, it is not apt to stick, unless it is very sticky snow; but if he gets off 10 feet and "slugs" snowballs at it, the snow is pretty sure to get in between the cracks and stay there. Naturally, with a high electrode voltage, we are apt to have good, solid, adherent deposits. By this term, "electrode voltage," is not meant the voltage across the terminals of the vat, but the voltage of the electrode against a standard electrode. In other words, we measure the electromotive force with which the cations are drawn from the catholyte to the cathode. This voltage can be measured by a potentiometer if we use the hydrogen electrode, or, in case we use a electrode which will not polarize with a current of several milliampères, by a Weston voltmeter.

The necessity of distinguishing between "electrode voltage" and "terminal voltage" cannot be too strongly emphasized.

Both "terminal voltage" and current density are useful terms in their place, but they do not tell us much about the electrochemical reactions which are taking place. "Electrode voltage," or "electrode potential," to use the more correct term, is the quantity that should be measured. Suppose we are refining a copper anode carrying gold values. We find that, with a certain curent density and a certain solution, we have a slime carrying 99.5 per cent. of the gold in the anode. Now, if we substituted for the copper anode a silver anode carrying the same amount of gold, we should find that quite a considerable portion of gold would be carried to the cathode. Measurement with the potentiometer against a hydrogen electrode would show the reason for the discrepancy in the difference of readings. The question of surface is a large factor. Some anodes are porous, and, on dissolution, present a larger surface to the current than measurements would indicate. Again, the current density is not uniform. The anode surface is not constant in chemical composition. It has been known for thirty odd years that the silver in copper concentrates in an outside layer. A few of these facts are mentioned to show that in electrolytic works conditions are rarely such as they are supposed at first glance, and the "electrode potentiometer" is a good instrument to use when we wish to learn bottom facts and with which to diagnose these unknown variations.

The writer was at one time employed in experimental electro-refining. It was found possible to gradually run the slimes from 4-ounce precious metals to 15-ounce, 28-ounce, 78-ounce successively. The potentiometer method of measuring the e. m. f. of the anode against the standard electrode was the best help that could be found whenever trouble arose.

The same method is of value in telling us what happens electrochemically at the cathode. The reading of potentiometer gives us exactly the relative forces which pull the cations out of the solution.

We know that it is necessary to have also a good supply of cations present in the catholyte, as well as to have a high "electrode voltage" of deposition. If a single salt were used, we should be obliged to use a concentrated solution to attain this condition. To use a high electrode potential in depositing, we should be obliged to use with a single salt a high current density. This would mean that the catholyte would be quickly impoverished of cations. In accordance with these facts, we find that all successful processes for making springy and elastic electro-copper in sheets use fairly high current density, strong solutions and keep the catholyte constant by some means of circulation. Just here is where the double salt, with its complex ion, plays an important *rôle*. It causes a high e. m. f. to be used in depositing, and it furnishes the catholyte with a good supply of cations by its continuous decomposition. A good electrodeposit is therefore obtained from the double salt for good electrochemical reasons.

The function of the double salt, in preserving a fairly constant cation concentration, is in line with the importance of concentration changes, as shown in the working of the lead accumulator.

The solution which has undergone electrolysis undergoes often permanent chemical changes, forming basic insoluble salts. These salts are either held partly or entirely in solution by the double salt.

In storage-battery work it is found that the bottom of a plate ages faster than the top of the plate. Analyze the top layer of the electrolyte and the bottom layer, and it will be found that the bottom becomes concentrated and the top dilute. This makes a non-uniform current density, and causes thereby lowered efficiency, because of local action of the vertical "concentration cell" set up.

In electrodeposition we use much higher current density and we have a soluble anode, while in the lead accumulator both electrodes gain in weight on discharge and lose in weight on charge. The action of a soluble anode is partly reversible, as in the lead accumulator. The irreversibility depends largely on these concentration changes. To counteract these changes and to keep the electrolyte of uniform composition is the function of the numerous devices for circulating the electrolyte, by blowing air through it, forcing the solution in a jet at the cathode or by moving the cathode, etc. A good part of the advantage found in hot solutions is due to the fact that they necessitate some circulation.

The effect of these concentration changes on the character of the bath is often permanent, as remarked above. If we use a high current density in electrolyzing the nickel bath, we have the formation of nickelic sulphate in the anolyte, and of nickelous hydroxide or basic sulphate in the catholyte. These last two compounds are, of course, insoluble in neutral solutions, and very slowly soluble in dilute acid solutions. They form a slime which renders the solution turbid, falls to the bottom of the vat, or, in extreme cases, will form a thick apple-green paint on the cathode.

By the electrochemical reaction above described the electrolyte becomes acid, and we have a "gasing" at the cathode, as the velocity of counter-reaction is slow. In the old Balbach nickel-refining process this sludge used to collect in the "well." By stirring this sludge with electrolyte which had grown acid, the solution was kept near the neutral point. Similar phenomena have been observed by the writer in electrolyzing iron or ferro-nickel. In one case a beautiful, dull, silver-white deposit will be obtained, while on a slight increase in current density the solution will have an insoluble sludge of dirty brown basic salt. The change is a very sharp one.

The formation of a cloudy precipitate or the presence of suspended particles of any kind from anode slime has, as is well known, a bad effect on the physical characteristics of electrodeposited metals. These particles have in few cases a conductivity exactly equal to that of the deposited metal, and, of course, in the case of basic salts are insulators. When adhering, as they often do, to the cathode, they cause a local distortion of the electrochemical field The lines of force are shunted round this particle, and build up the deposit at the

outer edge with great rapidity, as the current density is large there. These nodules, if allowed to grow, grow *"ipso facto"* with great rapidity and spoil the deposit, making it porous and brittle; and in the case of thick deposits "warty" and poor. A hydrogen bubble will cause the same trouble. The solution can be kept clear of these suspended particles by running through a filter or filter press, or allowing to settle in outside vat.

The use of a hot solution is bad, in that it accelerates the formation of these basic salts. For nickel, the use of a hot solution is often recommended, and this fact has been known for years. In fact, a Bristol, Conn., plater was using it practically in 1888. The work of Foerster showed that for depositing thick sheets the hot (50° to 60° C.) solution was desirable. Since Foerster's work it is often stated that it is impossible to deposit a thick coating of nickel from a cold solution. Perhaps the best piece of deposited nickel the writer has every seen was on the wires suspending a plater's basket. It was three-quarters of an inch thick, hard as steel and shone with a dull silver finish. A small current density was used, and this was the cause of the excellence of the deposit. This deposit was made from a cold solution.

The reason why electrodeposited nickel "curls up" (which is said to be prevented by hot solutions, but is only prevented in certain cases) is due, in the opinion of the writer, to the tremendous molecular strain under which nickel, or rather the nickel-hydrogen alloy, is deposited. We can obtain some idea of this by the fact that the electrodeposited nickel is electropositive to cast nickel by 0.25 to 0.05 volt, according to the potential at which it was deposited. This shows that the molecules are placed under an abnormal strain. Another bit of evidence proves this physically.

Nickel was electrodeposited on a malleable nickel cathode sheet, 18 x 12 inches, which fitted in a groove in the end vat, which was 12¼ inches wide. The groove was made of slats, ½ x ½ inch in cross section, nailed to the vat and painted with asphalt paint. The surface exposed was about 18 x 11⅛ inches. At the end of six days' deposit out of a hot solution, the electrolytic sheet, still adhering to the soft sheet, was wedged in so strongly that two men were required to pull it out. The whole sheet was now elastic. In addition to the potential energy of electrolytic solution, as measured by the potentiometer, there was also the potential energy of an elastic body under strain.

Now, it will be found that both these physical quantities diminish with time, and also with temperature. Take pure electrolytic nickel (by electrolytic nickel, of course, is meant nickel alloyed with an amount of hydrogen) and anneal it in a Bunsen flame. It loses both its elasticity and its "overvoltage." Allow it to stand, and it will gradually lose these same properties.

The "curling up" of electrolytic nickel is probably caused by the fact that there is an unequal strain between the inside and outside layer. The inside layer, when deposited, had the same abnormal strain, but with time this tension has become more normal by a slow annealing action. The outside layer has had, however, no time for the molecules to adjust themselves, and consequently the tension is greater on the outside than on the inside. Electrodeposited nickel tears itself from the cathode and curls up, just as a piece of paper curls up in drying, which is undoubtedly due to unequal strains of the inside and outside layers. The curling is always such that the outside layer is on the concave side of the bending.

It is also a fact that the contact to the original cathode will determine to a large extent whether the electrolytic nickel curls or not. For instance, if the plating be on a rough or matted surface, it will stick to this cathode when it would not stick to a smooth cathode. Nickel will stick to a clean, smooth surface when it will curl from the same surface which is oiled or graphitized. When a large current density is used, nickel will often stick to the sheet, but the whole plate will curl up unless the deposit be on both sides. If the current be interrupted for a short time and then continued, the nickel deposit will in many cases curl up where film of oxide, formed during interruption, has made a plane of weakness. Further facts could be adduced to point to the same conclusion—that the curling up of electrodeposited nickel is due to the unequal strains between outside and inside layers, and that hot solutions and low electrode voltage, which have been found to be favorable, are favorable because they tend to equalize these strains.

In conclusion it may be said that there are few better fields for investigation than that indicated in the title of this article. If such divigations as these lead anyone to explore this field thoroughly, the writer will feel more than repaid for putting his modest views before the electrochemical world.

Sidney, C. B., January 28th.

PIONEERS OF ELECTROCHEMISTRY—V.

WILHELM OSTWALD.

In one of his lectures on "Physical Chemistry," held at the celebration of the tenth anniversary of the University of Chicago, J. H. van't Hoff, while reviewing the historical development of physical chemistry, makes the following remark: "It is a rather small number of those who, working not always under the most favorable conditions, have contributed during the last fifteen years to the development of physical chemistry. Ostwald must be mentioned first, who, by his comprehensive activity as a teacher, by his surprising literary work, and by his talent as an organizer, has probably done more for the development of physical chemistry than many others."

A good deal of the work of Prof. Ostwald has had to do with electrochemistry, and he was indeed a directing force in the development of modern theoretical electrochemistry on the basis of the so-called theory of electrolytic dissociation. Even those who think that here too large a building was erected on too narrow a basis have never denied the "inspiring atmosphere of Ostwald's laboratory," and there is nobody who would not admit that Ostwald's work has done a great amount of good in stimulating and directing researches which are certain to bring fruits in the further development of electrochemical science and industry. It is thus highly appropriate that his name should be placed here among the pioneers of electrochemistry.

Wilhelm Ostwald was born in Riga, Russia, on August 21 (September 2d), 1853, as the son of a cooper. After having passed through a grammar school, he visited the Realgymnasium at Riga, from which he was graduated in 1871. As a boy he was mechanically inclined and his father wanted him to become an engineer, and was somewhat sorry that his son insisted on a purely scientific career. In January, 1872, he entered the University of Dorpat and studied for three years chemistry and physics, his most adored professors being C. Schmidt, A. von Oettingen, and Joh. Lemberg. In 1875 he became assistant in the physical laboratory of the university.

In the same year (1875) he published his first investigation on the mass action of water (*Jour. f. Prakt. Chemie*). In 1876 he published in the same journal a paper on volumetric chemical studies. The same subject was dealt with in the thesis for his master's degree (1877), and in the thesis for the degree of doctor of philosophy (1878). In 1878 he began his work as a university teacher by lecturing, two hours a week, on the theory of chemical affinity.

In the following years he published quite a series of papers on the subject of chemical affinity. Having been assistant in the chemical laboratory since 1875, he became in 1880 assistant in the physical laboratory. In the same year he married.

In the autumn of 1881, Ostwald became professor of chemistry in the Institute of Technology of Riga, the city of his birth. Here he remained for six years, and in this period his

"Lehrbuch der Allgemeinen Chemie" was written (1883 to 1886). Shortly after this well-known work had been finished, he, in conjunction with Prof. van't Hoff, founded in the spring of 1887 the *Zeitschrift f. Physikalische Chemie.*

In the autumn of 1887, Ostwald was called to the University of Leipzig, where he still remains as professor of chemistry, in special charge of the branch of physical chemistry. It was here that he developed his enormous activity.

Besides his papers published in various journals, but mainly in the *Zeitschrift f. Phys. Chemie,* Ostwald has written the following books: "Grundriss der Allgemeinen Chemie" (1889, 1890, 1899); "Lehrbuch" (1883-86, 1891); "Hand-und Hilfsbuch" (1893, 1902); "Geschichte der Elektrochemie" (1894-95); "Wissenschaftliche Grundlagen der Analytischen Chemie" (1894, 1897, 1901); "Aeltere Geschichte der Lehre von den Beruehrungswirkungen" (1898); "Grundlinen der Anorganischen Chemie" (1900).

In 1901 Ostwald founded the *Annalen f. Naturphilosophie.* Since 1883 he is the editor of the well-known series "Klassiker der Exakten Wissenschaften." In 1892 he published a German translation of Gibbs' fundamental thermodynamical papers. These papers, buried before in scarcely accessible transactions, became thus accessible to the general scientific public, and the German Ostwald was thus instrumental in making known the name of the greatest thermodynamical scientist of the United States. In 1897 and 1898 a new laboratory was built, according to the suggestion of Ostwald. The enormous work, done by his students in the old laboratory under his direction, and according to his suggestions, may be appreciated from the collection of their papers in four volumes.

In 1893 Ostwald founded the German Electrochemical Society. He was its recognized soul and heart, and to him is also due the recent change of the name into German Bunsen Society, which name was chosen to indicate the broader scope of physical chemistry in general.

In spite of his pronounced scientific progressiveness, Professor Ostwald possesses that conservative spirit which is achieved by the historical study of the development of science. Although firmly fixed in his scientific convictions, he is no fanatic. In the German Electrochemical Society he always advocated the co-operation of theorists and practical men. The number of his old students is legion; they are found wherever physical chemistry and electrochemistry are taught or applied, in universities and schools, as well as in the laboratories of chemical manufacturers, not only in Germany, but all over the world.

May Geheimrat Ostwald continue his fruitful activity for many years to come.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By GEORGE P. SCHOLL.

APPARATUS AND PROCESSES FOR THE ELECTROLYTIC PRODUCTION OF METALS AND COMPOUNDS.

Manufacturing Chlorates. R. Threlfall, Birmingham, England. Patent No. 716,789, December 23, 1902. Application filed May 2, 1902.

The inventor claims to have discovered that in order to obtain a high current efficiency in the manufacture of chlorates it is necessary to have a certain amount of free hypochlorous acid always present in the electrolyte, preferably about two grams HClO per liter. He proposes to obtain this by splitting off a part of the electrolyzing current and diverting it to an auxiliary cathode, arranged in a suitable porous vessel, either inside or outside the main electrolytic vat. There is thus more chlorine formed at the main anode than alkali at the main cathode, and the excess of chlorine at the anode is said to react with the hypochloride present in the electrolyte, according to the equation $RClO + H_2O + 2Cl = RCl + HClO$, R designating one atom of an alkali metal. HClO spontaneously breaks up as follows: $3HClO = 2HCl + HClO_3$ and $HClO_3 + RClO = RClO_3 + HClO$, the two reactions being continuously repeated. Electrolysis in the main vessel takes place without a diaphragm; the anode is preferably made of platinum or platinum alloys, and the cathode either of the same materials or of carbon. A regulating resistance is arranged in the path of the current to the auxiliary cathode, in order to stop or vary the action. With a current of 1,000 ampères, about 950 ampères pass to the main cathode and the remaining 50 ampères to the auxiliary cathode. Approximately 90 per cent. of the theoretical yield of chlorate is said to be obtainable by this process.

Apparatus for Producing Caustic Soda by Electrolysis. E. A. Allen, Rumford Falls, Me., and H. K. Moore, Lynn, Mass. Patent No. 716,804, December 23, 1902. Application filed December 27, 1898.

Fig. 1 shows a cross section of the apparatus. The underlying principle of its construction is the same as the Hargreaves apparatus, namely, the arrangement of the cathode on the outside of a diaphragm, and not in direct contact with the electrolyte. The cell has two end walls, connected at their upper ends by two bars a^1 a^1, thus leaving the longitudinal sides entirely open. The open sides are closed by a diaphragm *b* of asbestos paper or other substance, which will permit the free percolation of the electrolyte. On the outside of each diaphragm is arranged the cathode *c*, consisting of a series of layers of wire cloth or a bed of steel wool, in the form of a

comparatively thick sponge. The asbestos paper and the wire sponge are bent under the bottom plate, in order to make electrical contact with the long iron plate *d*, upon which the cells rest side by side. The anode consists of pieces of gas carbon *e*, cast in a lead frame e^1. A sheet lead jacket *f* dips into a groove a^6, filled with any suitable non-volatile hydrocarbon, such as coal tar, to form a seal for the chlorine. Suitable openings, capped by a glass dome *g*, are left in the cover of the cell to conduct the chlorine away. The plate *d*, which is connected with the source of the current, is inclined and provided with a trough at its lower edge, in order to receive the fluid resulting from the electrolysis. During electrolysis the solution percolating through the diaphragm trickles down through the cathode sponge from top to bottom, being constantly exposed to the action of the current on its way down, with the result that it reaches the plate *d* in the consistency of molasses and consists of caustic soda with only a small percentage of sodium chloride. It is stated that a current density of not less than 444 nor over 510 ampères per square meter of cathode surface produces the best results, and the diaphragm should preferably be made to permit a percolation of about 3 liters to each square meter of diaphragm surface in one hour. The temperature of the cell should not be increased above 80° C.

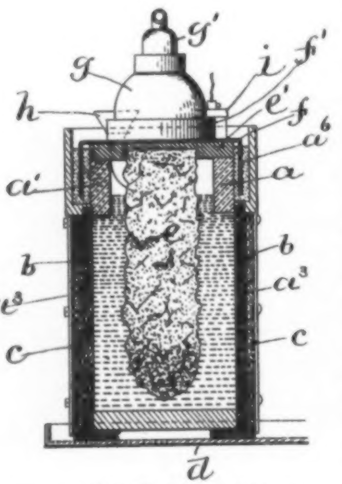


FIG. 1.—CAUSTIC SODA APPARATUS.

Electrolytic Apparatus. Max Haas, Aue, Germany. Patent No. 718,249, January 13, 1903. Application filed August 6, 1901.

The apparatus is an improvement on the well-known Haas and Oettel apparatus for the production of bleaching solutions. It aims at overcoming the loss of current incident upon the use of bipolar electrodes, and arising from the fact that the electrolyte itself forms a connection between the various compartments of an apparatus. In the present construction long, narrow tubes of non-conducting material are provided, through which the electrolyte has to flow in order to pass from one compartment into the other or from the storage reservoir into the various compartments, and thence to the collecting vessel. The idea is to oppose so much resistance to the current by the long pipe connection that it will be so much greater than the resistance within the compartments that practically all the current will flow through the compartments, and the loss become so small that it practically does not come into consideration. The bipolar electrodes are made of carbon, as in the older form of the Haas and Oettel apparatus. Motion of the electrolyte is brought about by the ascending bubbles of hydrogen, in substantially the same manner as in the German patents by the above inventors.

Deposition of Metals on Earthenware Articles. G. W. Laybourn, Hoke-upon-Trent, England. Patent No. 716,550, December 23, 1902. Application filed June 17, 1902.

The invention relates to the deposition of metals or metallic coatings on domestic, ornamental, sanitary and other earthenware articles, and its chief object is to deposit the metals after the articles have been specially prepared and brought to a highly porous condition. It is claimed that the conductivity of the water in which the articles are steeped before they are placed in the electroplating bath, and which fills the pores, greatly assists the deposition of the metals.

STORAGE BATTERIES.

Storage Battery. C. H. Clare, Quincy, Mass. Patent No. 717,351, December 30, 1902. Application filed March 1, 1902.

The invention relates to storage batteries in which the active material is held upon the face of the lead plates by separating plates of insulating material, and is intended to overcome the tendency of the active material to fall out from between the plates. For this purpose the inventor arranges so-called "units," groups of electrodes, held rigidly together by plates of insulating material, such as glass, gutta percha, etc., on the four sides and on the bottom. Such a unit consists, in the order named, of an insulating plate, a lead plate, a layer of active material, two porous earthenware plates with openings between them for the circulation of the electrolyte, another layer of active material, a lead plate, another layer of active material, two porous plates with openings as before, a layer of active material, a lead plate and finally another insulating plate. An insulating plate at each end and one on the bottom complete the "unit," which is rigidly bound together by two "suitable" binders, the nature of which is not given. The porous earthenware plates serve also the purpose of pressing the active material against the surface of the lead plates. The two outer lead plates are connected together to form one electrode, while the inner lead plate forms the other electrode.

Secondary Battery. I. Kitsee, Philadelphia, Pa. Patent No. 717,416, December 30, 1902. Application filed April 10, 1893.

Application for this patent was filed nearly ten years ago, and a whole host of patents have since been taken out in this country and abroad with the same object in view, namely, to prevent the buckling of the electrodes by providing for the expansion of the active material. The electrode in this construction consists of a rectangular frame of conducting material, presumably lead, in which is placed a band of conducting material bent into zig-zag form, so as to form spaces, which are to be filled with active material. Soft rubber bands are then placed around the electrode thus formed, and a perforated sheet of non-conducting material is placed on each side. In order to keep these sheets in position, a second series of rubber bands is placed around the whole. The active material is provided with holes to allow for the circulation of the electrolyte. The conducting band is bent in such a manner as to allow room for the expansion of the active material.

Secondary Battery. W. Morrison, Chicago, Ill. Patent No. 717,107, December 30, 1902. Application filed May 19, 1900.

The inventor says: "To form the red lead into a paste, it is usually mixed with dilute sulphuric acid. This produces a small quantity of sulphate of lead, and in drying the sulphate of lead slowly sets into the mass as it hardens. With this construction, however, when the charging is carried too far, the lead sulphate is changed to a peroxide of lead, the sulphuric acid is expelled and the bond is relaxed until the peroxide coating powders and crumbles away. The object of the present invention is to overcome this difficulty, and this I have discovered may be accomplished by using hydrofluoric acid, by mixing it with the lead paste forming the active material. Hydrofluoric acid being strongly electropositive, it will unite with the sulphuric acid of the electrolyte to form a fluoride of lead, which resists the seductive effects of overcharging and perpetuates the bond of the paste, so as to prevent the latter from crumbling."

Secondary Battery. W. Morrison, Chicago, Ill. Patent No. 717,108, December 30, 1902. Application filed August 5, 1901.

In this patent the inventor states that the same result as

described above may be obtained by using fluorine or hydrofluoric acid or fluoride of lead or ammonia, or other compounds of lead, to be mixed with the electrolytic solution of the battery.

Process of Preparing Storage-Battery Plates. R. C. Browne and F. Balch, Salem, Mass. Patent No. 715,663, December 23, 1902. Application filed April 21, 1902.

The inventors claim to have discovered a new process for preparing storage-battery plates prior to their formation. The following procedure, as described by them, is stated to have given the most satisfactory results, though they do not confine themselves to the exact proportions or temperatures, which may be varied to some extent: "To 30 ounces of sulphuric acid, at a temperature of 204° F., preferably contained in an open vessel or beaker, we add 17 ounces of potassium nitrate, and allow the temperature of the mixture to fall to 185° F. We then add 16 ounces of water and stir in 1½ ounces of ammonium sulphate, and when red fumes are given off we add 74 ounces more of water and allow the solution to cool to 79° F., at which temperature it is maintained while the plates are being treated. In our experience plates of lead immersed in the above-described solution and allowed to remain but three hours, while the temperature is maintained at 79° F., become heavily incrusted with scale in many superimposed layers, clinging together and of a porous nature, with a distinct grain. . . . When the incrustation or coating of lead has been perfected in the solution, the plates are ready for forming by electrolysis." The inventors state that, as nearly as they have been able to ascertain, the scale is a lead sulphate, but they are led to believe by certain characteristics of it that a metallic salt is combined with the sulphate of lead, which hardens the latter and renders it more adherent.

Storage Battery and Method of Preparing Electrodes Therefor. L. Paget, New York City. Patent No. 717,610, January 6, 1903. Application filed January 10, 1900.

The specification describes a new form of electrode, made up of successive layers of spongy lead compressed to the density of sheet lead, 11.4 or thereabouts. Direct pressure—that is, the pressure of a press as distinguished from that of rolls—is necessary, and a pressure of from 2 to 3 tons is sufficient. The specific gravity of the compressed plates must not fall below ten, which involves loss of durability. If the specific gravity is less than about nine and one-half, the plates will be entirely unsuitable. An important feature of the invention is that the plates are built up of successive thin films, each not more than about two-hundredths of an inch in thickness. The spongy lead is applied on opposite sides of the element for successive compressions, with the result that the density of the layers will increase from the surface inward, and the plate will thus resemble a Planté plate. The thickness of the finished electrodes is stated to be about a quarter of an inch.

Storage-Battery Electrode. L. Paget, New York City. Patent No. 717,609, January 6, 1903. Application filed January 10, 1900.

This specification claims the electrode formed by the process outlined in the preceding patent of the same inventor.

Method of Preparing Storage-Battery Electrodes. L. Paget, New York City. Patent No. 717,608, January 6, 1903. Application filed October 19, 1899.

Electrode for Storage Batteries. L. Paget, New York City. Patent No. 717,607, January 6, 1903. Application filed September 8, 1899.

These two inventions relate to a new form of storage-battery electrode and the process of preparing it. The construction of the electrode is illustrated in the accompany Fig. 2. It is formed of a series of small plates A, connected by lugs C to a common conductor B. Each of the small plates consists of a thin sheet, formed by compressing precipitated lead, and is provided with vertical corrugations. An elastic frame D of vulcanized rubber incloses the plates on the bottom and the sides. This construction permits the plates to expand and contract transversely to the corrugations during the process of charging and discharging. Each of the plates A is preferably not over an inch in width, and the thickness of them—that is, the depth of the corrugations and of the frame D—is from a quarter to a third of an inch. The sheets of lead, corrugated to form the plates, are preferably not more than one-half to one millimeter in thickness.

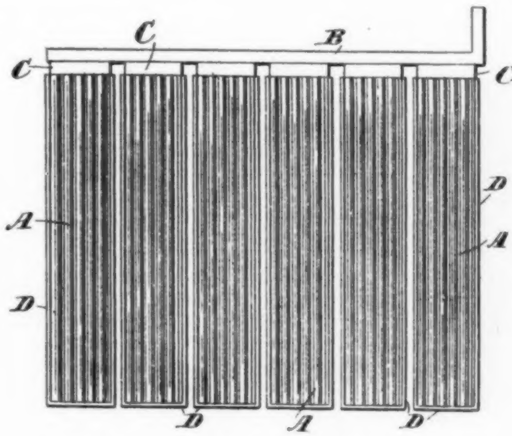


FIG. 2.—STORAGE-BATTERY ELECTRODE.

Electrical Storage Battery. H. K. P. Barham, Portsmouth, England. Patent No. 718,045, January 6, 1903. Application filed December 2, 1901.

The battery is constructed out of a number of strips of sheet lead, arranged one above the other. Each strip is formed like a tray in its middle portion, with folded extensions at both ends. Between all the contiguous surfaces of the folding extensions and the trays are interposed sheets of absorbent or porous material, such as blotting paper, unsized paper, asbestos, etc. The absorbent sheets are saturated with an electrolyte, preferably dilute sulphuric acid.

Secondary Battery. J. W. Madigin, Toronto, Canada. Patent No. 718,489, January 13, 1903. Application filed February 5, 1902.

This battery, as shown by Fig. 3 in cross section, consists of a glass or rubber cell A, in which are arranged four electrodes B, B, B and C. The electrodes are separated from each other by rectangular plates or sheets F of fiber, cellulose or wood fiber, which is chemically treated with a neutral salt. The separating plates are porous, and consequently the electrolyte,

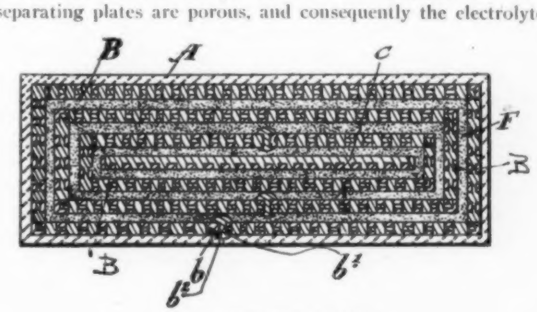


FIG. 3.—STORAGE BATTERY.

by capillary attraction, is drawn up from the bottom of the cell. The electrodes B are rectangular in form, and are constructed from a single sheet of metal folded at b and having its free ends at b^1. The folded end b and the free ends b^1 are burnt together into the groove b^2. In this way a double plate is formed, leaving a space between, which is filled with active material. The plates are perforated in order to insure circula-

tion of the electrolyte. The inner plate C is formed with horizontal corrugations, and the space between the corrugations is filled with active material.

Electric Battery. M. R. Hutchinson, Upper Montclair, N. J. Patent No. 718,205, January 13, 1903. Application filed April 8, 1902.

This invention relates to electric batteries, both primary and secondary, and especially to the "dry" or "semi-dry" class. The inventor states that, as such cells generally contain a free space for the electrolyte at the top, it has been found in practice, when they are replenished, that the generated gases force the liquid out of the vent hole, which is very objectionable, especially if the cell is carried upon the person. In order to overcome this, he arranges the space for the electrolyte at the bottom or at the side of the cell, providing them with a liquid-tight plug, through which liquid can be poured into the cell after turning it upside down. When filled, the plugs are replaced and the cell turned right side up. The porous material interposed between the electrodes reaches down into the reservoir for the electrolyte, and by capillary attraction draws the liquid up.

Battery Installation. S. Lake, Bridgeport, Conn. Patent No. 716,844, December 23, 1902. Application filed and divided June 23, 1902.

"The present invention has for its object to prevent the escape from the storage-battery compartment of a submarine boat into the living quarters of the fumes or gases commonly set free from the battery fluid in the charging of batteries, and also to maintain the atmospheric pressure in such compartment substantially uniform and at a pre-determined tension, in order to prevent the rising of such pressure above a dangerous limit." Mechanical arrangements for accomplishing these objects are described in detail in the specification.

Galvanic Cells.

Electric Battery. H. Halsey, New York City. Patent No. 717,394, December 30, 1902. Application filed April 18, 1902.

"This invention," says the inventor, "relates to that class of primary batteries invented by me in which one or both elements, wholly submerged, are revolved during the operation of the battery. . . . I employ in a battery a movable element and means for moving said element at any desirable rate of speed, and, inasmuch as the output of the battery will vary proportionately to the difference in speed between the element and the electrolyte, the output of the battery may be varied by varying the speed of the element. To maintain the constancy of the output, I provide means for keeping the surfaces of the elements clean." The cell shows a movable and a stationary electrode, the movable electrode being rotated by an electric motor run by current furnished by the cell itself. The revolving electrode carries brushes which rub against the surface of the stationary electrode for the purpose of keeping it clean and preventing polarization. Provision is also made for introducing depolarizing agents, such as bichromate of potassium. The mode of operation is described as follows: "The initial output of the battery is always sufficient to start the motor, and thus revolve the movable element. If the element remains stationary, the output of the battery will be first at its maximum, but as polarization increases the output will proportionately decrease; but, as the initial current from the battery starts the revolution of the element or electrolyte, the output of the battery will remain at maximum if the speed of the element or electrolyte be also maintained at its maximum." The idea of having to buy a motor with every galvanic cell is certainly a novel one, but it is doubtful whether it will find much favor with the general public.

Electric Battery. H. Halsey, New York City. Patent No. 717,395, December 30, 1902. Application filed April 18, 1902.

This invention covers substantially the same ground as the preceding, showing only a different mechanical arrangement for effecting depolarization of the electrodes. The motor for driving the movable electrode is again very much in evidence.

Battery. Louis Begeman, Cedar Falls, Iowa. Patent No. 718,076, January 13, 1903. Application filed January 7, 1902.

The construction is intended to be an improvement on the Lalande type of battery, in which the positive pole is formed of any suitable metal surrounded or covered by oxide of copper, which acts as depolarizing agent, the negative pole by zinc and caustic soda or potash used as electrolyte. The containing vessel, of tin, copper or iron, is corrugated, and the depolarizing agent, copper oxide, is supported in these corrugations. In order to keep the copper oxide in place, the vessel is lined with wire gauze, which in turn is covered by a shield of muslin or similar material to guard against any particles of the oxide falling through. This material is again supported by inner lining of wire gauze or netting, preferably of elastic metal. The zinc electrode is formed in the shape of a hollow cylinder.

Electric Battery. Georges Rosset, Paris, France. Patent No. 716,762, December 23, 1902. Application filed February 20, 1901.

The inventor proposes a new depolarizing agent, namely, the cuprates of the alkalies, and especially the cuprate of ammonia. The depolarizing agent may be obtained by introducing concentrated ammonia solution or ammonia gas into a concentrated solution of sulphate of copper and re-dissolving the precipitate in an excess of ammonia. The same procedure may be followed in order to produce the cuprates of potassium or sodium, only the excess of alkali intended to re-dissolve the precipitate is added in the presence of an organic substance, such as glycerine or tartaric acid. In order to avoid diffusion of the depolarizing agent, the inventor makes use of a porous vessel, in the pores of which he deposits a membrane of ferrocyanide of copper by substantially the same procedure as is familiar from the description of Pfeffer's osmotic experiments. A plate of carbon, forming the positive electrode, is placed in the porous vessel, the vessel filled with a concentrated solution of cuprate of ammonia and placed into an outer vessel containing a concentrated solution of sal-ammonia and a zinc rod as negative electrode. The action of the depolarizer is explained as follows: "Polarizing hydrogen appears at the carbon electrode, and reduces the cuprate solution to cuprite, but stops at this stage, because the reduction of cuprate to cuprite requires less work than the reduction of cuprite to metallic copper. The diffusion currents, aided by the lightness of the freed ammonia, bring this cuprite to the surface of the cell, where the oxygen of the atmosphere converts it back into cuprate, which, being denser, sinks back. During the operation the depolarizing agent consists of a mixture of cuprate, cuprite, deposited copper sometimes, and dissolved free ammonia; and this mixture, by self-regeneration, due to oxidation in the atmosphere, yields finally cuprate of ammonia."

Electric-Battery Compound. G. Bastedo, Brooklyn, N. Y.

This compound is intended for use in forming lead peroxide on the positive pole electrode in a lead and zinc battery, and consists of dilute sulphuric acid, 15 pounds; nitric acid, 50 grams; bisulphate of mercury, 1 ounce. The nitric acid and bisulphate of mercury are first thoroughly mixed, then the dilute sulphuric acid is added, and the whole thoroughly mixed again, when the compound is ready for use.

Diaphragm for Batteries. F. A. Decker and W. P. Divine, Philadelphia, Pa. Patent No. 717,549, January 6, 1903. Application filed April 9, 1902.

The diaphragm is made of clay, molded and baked, with reinforcing ribs and raised edges. The inventors claim to have found that the efficiency is greatly increased and the resistance greatly reduced by molding and baking the diaphragms of greater thickness than required, and then reducing the surfaces, with the exception of the reinforced portions, by

grinding or sand-blasting until a thin body of porous character is produced. Carbon diaphragms may be substituted for those of clay.

MISCELLANEOUS.

Process of Coating Phonograph Records. T. A. Edison, Llewellyn Park, N. J. Patent No. 713,863, November 18, 1902. Application filed June 16, 1900.

In this specification T. A. Edison discloses a new method for coating phonograph records. Formerly he accomplished this object by causing the formation of an electric arc between two bodies of the metal of which the deposit was to be made

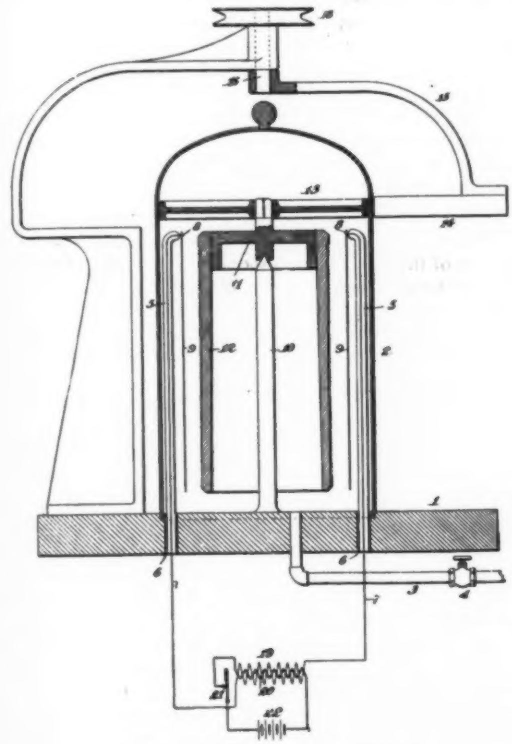


FIG. 4.—PHONOGRAPH RECORD APPARATUS.

in a vacuum, but it has been discovered that the rapidity of the process is increased and the disadvantages, such as injuring the delicate material by the heat of the arc, are avoided by the use of a silent discharge of electricity at high tension. Such a silent discharge may be produced from an induction coil of large capacity, or from a Helmholtz induction machine. The creation of a silent, or practically silent, discharge between two electrodes results in the vaporization of the metal, and the metallic vapors are carried directly toward and upon the record to be coated. The precipitation takes place most uniformly when the record is rotated, and, as the proper vaporization of the metal is only carried on in the presence of a high vacuum, the rotation is accomplished by a magnet outside the vacuum chamber. Fig. 4 illustrates the apparatus. A vacuum chamber 2 rests upon a base 1, and an exhaust pipe 3, to which an air pump or Sprengel pump can be attached, leads to the interior of the jar; 5, 5 are two supporting arms, preferably of glass, insulated from the base by hard rubber rings 6, into each of which a conductor 7 is introduced, with a hook 8 at its upper end. From each hook is suspended a strip or foil 9 of the metal, preferably gold, with which the record is to be coated, which strips serve as electrodes. A standard 10 mounted between the electrodes carries a rotating head 11, in which is supported a phonograph record 12. An iron or steel armature 13 is adapted to be rotated by a magnet 14, supported by arm 15 from shaft 16, carried by bracket 17 and rotated by pulley 18. In operation, the conductors 7, 7 are connected with the secondary of a large induction coil 19; the record is rotated, and the metal vaporized by the discharge is deposited upon it in an infinitesimally thin film. After that the cylinder is removed to a plating bath, where it receives a heavier deposit; and then the original record is removed, either by melting it out or by shrinking it from the deposited metal, leaving an absolutely accurate matrix of the original record.

Apparatus for Purifying Water. H. M. Livor, New York City. Patent No. 718,485, January 13, 1903. Application filed March 7, 1902.

The apparatus is shown in the accompanying illustration, Fig. 5, in which A represents a containing vessel for the purified water, made preferably of insulating material. F is a vessel containing an interior filtering chamber F', the lower end of which is provided with a cylindrical wire gauze or netting G, filled with sand M. O is a connection between filter and supply chamber. The electrolysis of the water takes place in vessel B, which is constructed of insulating material, and has at its bottom a flange, with which it fits into vessel A. A closely-fitting metallic ring E', made preferably of aluminium, constitutes one electrode. The other electrode, arranged concentric to the first, consists of an aluminium cylinder C. L, L are brackets on the inner surface of the electrode C, upon which rests an insulating disk H, supporting a strong spiral spring S, the upper end of which bears against a similar disk H' secured to the bottom of the metallic water-supply chamber E, which rests normally with its bottom on the cylindrical electrode C, thus making good electrical contact therewith; *b* and *b'* are binding posts connected with the respective electrodes. In operation, the water flows from chamber E through cock I and tube J into the annular space between the electrodes. There it is subjected to the action of the current and overflows through P and the tube H into the filtering vessel F, then upward through the wire gauze G and sand filter M through

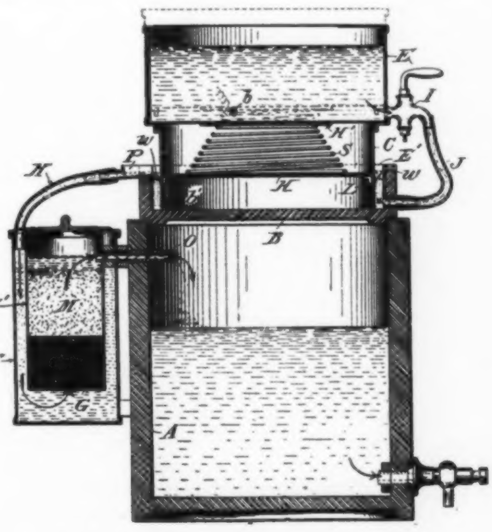


FIG. 5.—APPARATUS FOR PURIFYING WATER.

the pipe O into the container A. When the level of the water falls too low in vessel E, the spring S comes into action and lifts the vessel into the position shown in dotted lines, thus interrupting the contact between vessel E and the electrode C. The apparatus can be quickly disconnected, and the filter easily taken out and cleaned.

Process of Electrolytically Preparing Metals and Alloys for Lithographic Purposes. O. C. Strecker, Cologne, Germany. Patent No. 716,306, December 16, 1902. Application filed April 19, 1900.

The inventor claims: "The process for preparing metal

plates and alloys for lithographic printing, consisting in preparing the plate by preliminary grinding, rinsing, subjecting to an acidulated watery solution, washing and drying, fixing the negative upon the surface thus prepared, coating with gum arabic, treating with lithophine after the gum arabic has tried to dissolve the greasy substance, washing the plate with water to free it from the gum arabic, dusting with powdered colophane and rubbing this off, then submitting the plate as an electrode to electrolytic action in a solution of salts and gum arabic." The plate is used as anode in an electrolyte composed of a solution of 2.5 per cent. of fluoride of sodium. The density of the current is 0.5 to 0.9 ampères per square foot, and the action may last from two to five minutes. Zinc plates are preferred, on account of the cheapness of the material and the exceedingly good results obtained. An alternating current may also be used, in which case the electrolyte will be a solution of borax neutralized with boric acid 2 per cent. strong. By using this method, the current oxidizes the plate to ZnO, which is then treated with a weak solution of acid, preferably phosphoric acid. In special cases an electrolyte of a mixture of 3 ounces of ammonium silico fluoride, 3 ounces of ammonium nitrate and 3 ounces of gum arabic in 1½ pints of water is employed.

LORD KELVIN AND GEORGE WESTINGHOUSE.

At Claridge's Hotel, in London, on the night of January 9th, Mr. George Westinghouse entertained at dinner a large company of British railway managers, financiers and scientists. Two speeches were made of unique interest. One of these was by Lord Kelvin, the other by the host of the occasion. Although no electrochemical subjects were touched upon, these speeches will certainly be of particular interest to our readers, as they are characteristic of the speakers and as the subject of specific American methods in engineering discussed by Mr. Westinghouse should be of general interest.

Lord Kelvin said:

"At this dinner of friends I would like to express a common sentiment which all must feel, our appreciation of the qualities of our charming and beloved host, Mr. Westinghouse. I am sure that Mr. Westinghouse's coming to England reminds us all of the advantages that England has derived from his genius and perseverance and grand skill in bringing out for the public good so many of the results of science and inventiveness. There are many railway men present at this table and many passengers by railways, which means that every inhabitant of our country is represented here. When people belonging to these two classes—the railway men and the traveling public of Great Britain—are gathered together, as now, we can scarcely see Mr. Westinghouse without feeling how much we owe to him for the Westinghouse brake.

"But Mr. Westinghouse has not stopped with his brake. He has gone on, and on and on in America, flashing over again on this side of the Atlantic and bringing his energies here. The present development of the electric industry in the United Kingdom owes its growth largely to him.

"'Largely' is a small word to express how much we owe to him. I do not wish to enter into any comparisons of superlatives, but I do not think any man in the world of engineering could be named to whom more is due than to Mr. Westinghouse for his work in electric engineering.

"Other things besides mechanical engineering and electrical engineering we owe to Mr. Westinghouse. We owe to him the bringing to England, and causing to be appreciated in England, American methods—American methods in a certain way which I may refer to without invidious comparison. American methods of industry and resolution and determination, which are also English methods, because they have been inherited from England. Here it comes back to us with compound interest in the shape of Mr. Westinghouse, and I am sure that we all feel that we are largely indebted to him for what he has done for us, what he is doing for us and, in advance, for what he is planning to do for us in the future.

"We appreciate all this, and we appreciate him as a kind friend, a genial host and entertainer. I ask you to join me in drinking the health of Mr. George Westinghouse."

The toast having been honored with enthusiasm, Mr. Westinghouse rose to respond. He said:

"I wish to thank our distinguished scientific friend, Lord Kelvin, for the complimentary language he has used about me. And I would like to say to all you railway men here present that my life has been very much associated with your calling. I invented the brake of which Lord Kelvin has spoken when I was scarcely twenty-one years old, and thus became acquainted with railway men when the railway industry was rather a poor one compared with what it is to-day. Since then I have closely followed railway operations, becoming acquainted with almost everything that is being done in them; and it is particularly my friendship with railway men which has prompted me to go forward in my work with an interest and keenness that probably would not have resulted from ordinary commercial motives.

"Lord Kelvin has been good enough to refer to my coming to this country. I came here thirty years ago, and for ten years or so I was here about half the time. At that time it was very difficult to get any new thing done in England. I often wanted to sit down and cry, because I could not get anyone to believe in anything. I wanted in those early days to try an iron brake shoe, because, on account of rapid wear, we couldn't keep the wooden one adjusted. I had to beg and beg to be permitted to put a set of metal brake shoes on one tender on the Caledonian Railway. Finally I succeeded. You all know that nowadays all the railway shoes or blocks are made of cast iron or other metal, and are used upon all the wheels of the train.

"Lord Kelvin has alluded to 'American methods.' May I say that one of your English difficulties is inherited I think in an old-world, highly-developed country. After a man (or a nation) has worked prosperously for a long time, he opposes improvement or suggestion, thinking: 'What I have is good enough. I won't try a new thing.' In America, however, the necessities have produced different results. Lord Kelvin speaks of England having sent many men to America. It has also sent to us many ideas. If you take up the American patent records and follow the cases in litigation especially, you will find that among the references cited many are of English origin, some of them containing ideas so complete the wonder is that the inventions disclosed were not established fully and completely in your own land. These records seem to show that Americans and Englishmen have invented the same thing many times.

"In America, however, we have always been short-handed with regard to labor. We have been obliged to find methods whereby one man may accomplish the work of two or three men as compared with your practice here. We have had the best men from Europe—Englishmen, Germans, French, everybody, skilled men, highly-trained men, as well as laboring men. We have combined their experience with our own, coupled it with our necessities, and have thus accomplished results unattainable in a country like this, where you have more labor than you can well keep employed.

"As an illustration of what has been accomplished by the use of electricity in a great industry, I may cite the Homestead Mills of the Carengie Co. Mr. Schwab, whose name is well known to you, is a genius in his way, particularly in the management of men; he is a master in organizing and directing men. Mr. Carnegie believed in him, and if Mr. Schwab made a suggestion in regard to the use of new appliances, even if it involved the tearing down of an old mill and putting up a new one, the new one was ordered. What Mr. Schwab thought should be done was done. As a result of such progressiveness we may see the splendid mills at Homestead, where they pro-

duce, with about 4,000 men, three times as much steel as the Krupp works produce with 15,000 men. The results are simply wonderful. You can start there to-day, in a building containing steel-melting furnaces, and you will there see three men mounted on a car with the charging apparatus, which is moved and operated by electricity. With a few movements of this ingenious contrivance three men charge 20 furnaces, which, prior to the use of electricity, would have required the labor of over 200 men.

"You may go into the yard of the Homestead Mills, where they pile the metal in stock. This yard is covered by a system of overhead cranes, and the result is that not only here, but in the mill and in every other place, you may see great weights lifted and many undertakings going on without a single man exerting himself a bit—working not half as hard as I am working now.

"I took some English friends to Homestead. Mr. Schwab, after guiding us through several departments, said: 'I will now show you where we turn out 750 tons of plate girders per day.' The mill was in the shape of an L. We went into the short end of the L, where the furnaces were fed by natural gas, of course, requiring no stokers. The end at which we entered had a rather low roof, and there was in a sight a contrivance like a battering ram in front of the furnaces. Two workmen were sitting down eating their dinners near by; no one else was present. I thought: 'Mr. Schwab has made a mistake; he has asked us to see a mill that is not in operation.' But we went through the mill, which was about 200 feet long. Suddenly we heard a rattle, and then saw a truck approaching loaded with a big ingot. No one touched the truck or the ingot. The load came to a platform; the crane overhead dropped a pair of tongs and quickly put the ingot on the roller table, and as it moved along to the great rolls it was automatically kept in place. The adjusting screws of the rolls were turned by little electric motors, and not a man in that house did a bit of work. It was just as easy as what you are doing now—looking on. We went back to the furnaces. There was a fifteen-year-old boy seated in a little place called the 'pulpit.' He was able, merely by the movement of levers, to open at will any of the furnace doors and move the car along. And we saw this car come in front of a furnace and the charging machine approach and take out of the open furnace a hot ingot, which was dropped on the car and moved off to its work. There was this boy doing absolutely no hard work, and his mill was turning out 750 tons of steel plate each day. My English friends said: 'England has no chance in competition with such methods.'

"Now, all this sort of thing came about in America because of our necessities. We hadn't men enough to do our work. There was a premium in favor of those who could invent machines to work, and thus supply the deficiency.

"At the Carnegie Mills we went to see three blast furnaces. They were making 1,800 tons of pig iron in twenty-four hours. We saw only two or three men on a truck, which was moved automatically. These men were letting the ore run from shoots and mixing it in the required quantity; and when they had filled a truck it was carried up and its contents dumped into a furnace, whence it returned for another load. They were running the metal into an immense receptacle, into which the metal from all three furnaces was mixed. From this place the metal was taken as required, put into a special tank, mounted on a car and taken to Homestead, two or three miles away, to be poured into the furnaces. One heating only was required.

"I refer to all this simply to illustrate the immense advantages we have had in America, and the kind of experience I have been able to bring to this country, and to which Lord Kelvin so generously alluded, and which I hope will be not only useful and profitable, but will establish for the company I represent a name and a position which you will all regard as most satisfactory.

"I want to thank you very sincerely for the kind expressions with which you have greeted me, and especially for your acceptance of my invitation to inspect this evening a couple of inventions, one of which, the Hewitt mercury vapor lamp, is a complete and accomplished thing. The rays of this light are not very pleasant as yet, but the light is likely, however, to be of great value. The other invention, the Hewitt static converter, is quite new, and its object is to convert alternating currents into direct current at so low a cost in comparison with the sums which have heretofore been expended for equivalent results that it is likely, when fully perfected, to cause an immense stimulus in regard to the use of electricity in all parts of England, and particularly in the agricultural parts of the country for farm work and for moving all kinds of vehicles.

"I have taken advantage of these inventions to invite you to see them as my guests, and I thank you for having honored me with your presence to-night."

SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

BY CARL HERING.

INDUSTRIAL ELECTROCHEMISTRY.

Nickel Industry.—What seems to be a good statistical review of this industry in Canada is given in the January 9th number of London *Engineering.* The Canadian and Orford Copper Companies, which have been consolidated with the International Nickel Co., are still the most important producing concerns in the Dominion. The principal works of the Canadian Co. are at Copper Cliff, which covers 16,000 acres of the best mineral land in Ontario, and last year a feature of the company's business was the opening of an immense deposit of nickelliferous pyrrhotite and copper pyrites at the Creighton Mine. Operations were commenced in July, 1900, and now the surface plant is producing from 500 to 600 tons of ore daily for shipment to the roasting yards at Copper Cliff. There have recently been completed extensive smelting works, three-quarters of a mile southwest of Copper Cliff, and these have been utilized for the re-treating of low-grade mattes produced at the Copper Cliff smelters, with the result that their metal contents have been raised from 30 to about 70 per cent. This result is effected by crushing, grinding, calcining and re-smelting the mattes, thus getting rid of a great deal of the rock matter, iron and sulphur and producing an article much nearer the point of refinement and separation of the metals. For the final separation of the copper and nickel, this material is sent to New Jersey. The process includes a series of smeltings with various alkalies, followed by an electrolytic treatment for the purpose of producing pure nickel. One of the companies outside of the combination is the Mond Nickel Co., whose mines at Victoria have been very considerably developed during the past year, the Bessemer process having been put down for turning out the matte. The product is a high-grade article, carrying about 80 per cent. metallic contents in equal proportions of nickel and copper, the iron in the one being at the same time entirely eliminated. This matte is brought to England, where it is refined at the Swansen works by Mond's own process. During the past ten years 1,306,722 tons of nickel,

copper and copper ore, producing 26,606 tons of metallic nickel and 28,070 tons of metallic copper, have been produced in Ontario, the value of the nickel being over $20,000,000 and the value of the copper nearly $6,250,000. The rate of development has been very much greater during the last five years than in the first half of the decade. The most striking development has been in the production of high-grade matte, which in 1897 only amounted to 328 tons, whereas last year it was 15,546 tons.

Electrometallurgy.—In the continuation of his series on electrometallurgical problems in the Lond. *Elec. Rev.*, January 9th, BEADLE discusses the manufacture of aluminium, magnesium and sodium.

Separation of Metals from their Ores.—It has been the cause of some surprise that so little attention seems to have been given to the possible application of electrostatic forces to the separation of metals, such as gold, which often exists in very fine particles. The explanation is probably that the forces are too small. It appears, however, that NEGREANO has had some success in this direction, as he describes such a method in *Comptes Rendus*, December 15th, an abstract of which is in the Lond. *Electrician*. His method is based on the following experiment: A disk is cut out from the center of a metallic plate, and the plate and disk are connected with the two poles of a Wimshurst machine. If now a powdered mixture of sulphur and red lead is blown upon the metallic surface through a wooden sieve, the sulphur will be deposited upon the disk and the minium upon the other plate, or *vice versa*. This is due to the frictional electrification of the two powders in passing through the wooden sieve. He then mixed pulverized silica rock with malachite, iron oxide and copper oxide, and found that the metallic particles could be separated from the silica in the same way. In the case of a quartz rock containing limonite, the separation was easily brought about; also in separating pyrites from a matrix of lignite. The author proposes to employ this method for the separation of gold from gold dust.

Electrolytic Rectifier.—In the storage of electrical energy, mechanical methods fail and electrochemical methods must be resorted to in the storage battery. It seems that, similarly, though to a less degree, electrochemical methods may succeed in partly replacing mechanical methods in the rectification of alternating currents and in making cheap condensers. While it does not seem likely at present that the electrolytic rectifier will supersede the present converter or the motor generator, yet there is quite a field of its own, especially for converting small quantities, when moving machinery would be objectionable or expensive. Much has been written about the aluminium rectifier, and it seems that the original experimenters have abandoned it. It is therefore of interest to see that it is now being put on the market in France as a commercial apparatus in a new form, devised by NODON. The London *Electrician*, January 23d, gives an illustrated description, from which the following is taken: Fig. 1 shows the construction of the electrolytic "valve," as it is called by the inventor.

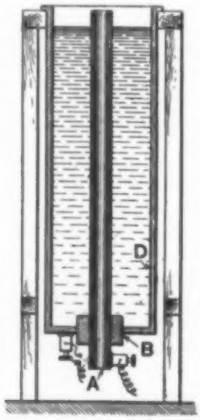


FIG. 1.—RECTIFIER.

It is extremely simple in design, and consists merely of a hollow cylinder A of a zinc and aluminium alloy immersed in a solution of ammonium phosphate. A containing vessel D of iron forms the other electrode, from which the cylinder A is insulated by the rubber plug B. On starting the valve, it merely acts as a liquid resistance, and does not choke back one-half of each alternation. This, however, only lasts for a very brief time, and after a few minutes a film commences to form on the surface of the aluminium electrode. It is this film which permits current to pass in one direction only. In order to utilize both half waves of the alternating current, the Graetz arrangement is used, as shown in Fig. 2. When used in connection with polyphase systems, the apparatus becomes rather more complicated, and it is necessary to use a number of cells equal to twice the number of wires used in distribution. For instance, six would be required for a three-wire, three-phase system. Each cell may be used for rectifying a current having from 50 to 140 volts, but when the voltage exceeds the latter figure two or more cells must be connected in series, allowing 140 volts as a maximum for each cell. Regulation in connection with these valves, having a capacity of more than 4 kilowatts, may be effected either by a choking coil on the alternating current side of the apparatus or by the adjustment of insulating sleeves, which may be made to cover or expose more or less of the aluminium-zinc cylinders. The efficiency is claimed to remain practically constant for all loads, and to seldom fall below 75 per cent. The loss consists in a reduction of 10 to 12 per cent. of the e. m. f., and of a leakage of alternating current within the rectifier corresponding to from 10 to 12 per cent. of the energy utilized. This energy is dissipated in heat which is liberated within the cell, and causes the temperature of the latter to rise to almost 50° C., after which radiation from the metallic casing prevents a further excessive rise. The frequency, within ordinary limits, appears to have no effect on the efficiency of the apparatus. The apparatus is put on the market in groups of four cells, connected as in Fig. 2. These four cells are put together in a frame, and below them a fan is provided; the aluminium cylinders being made hollow, a strong cooling draught passing through them. The current density is made at about 5 ampères per square decimeter of active surface of aluminium. NODON has also designed an electrolytic condenser on the same principle as his rectifier, which possesses a considerable capacity for its size, for use in starting alternating-current motors and for similar purposes. The rectifier is now being put on the market in sets of cells large enough to deal with 10 kilowatts at the maximum voltage of 140. The price of a complete set of four cells, having a capacity of 5 kilowatts for a single-phase circuit, is $150. The writer of that article remarks that "this price would appear to be almost prohibitive in the case of motors connected to single-phase circuits, but, as the construction of the valve is simple, it may safely be inferred that the selling price would be considerably reduced if there should be a real demand for this apparatus."

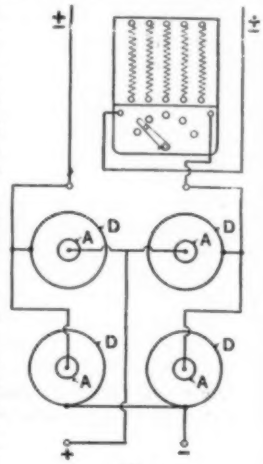


FIG. 2.
ARRANGEMENT OF FOUR CELLS.

An account of some tests made with this apparatus is given by HOSPITALIER in *L'Ind. Elec.*, December 10th. The tests were made at the School of Industrial Physics and Chemistry of the City of Paris. Four cells were used, and were arranged like a Wheatston bridge, as first used by Graetz for this purpose. One of the diagonal circuits is supplied with the alternating current to be rectified, while the other contains the apparatus in which the rectified current is to be used. As is well known, the former arms each contain one of the "valves." This arrangement enables one to utilize both half curves of the alternating current in tne same circuit. The frequency of the alternating current in the experiments was 42, and an electrolytic valve of the 5-ampère type was used. The rectified cur-

rent was used to charge a storage battery of 42 cells in series. The wave forms of the currents and e. m. f.'s were determined by means of the ondograph, and are reproduced in diagram. The efficiency of the rectifier was found to be about 70 per cent., and the wasted energy appears in the form of heat, so that the temperature of the electrolyte increases. This is said to cause no other inconvenience than the evaporation of the liquid, requiring that water must be filled in at intervals. The electrolytic rectifier behaves like a condenser, the current being about one-quarter period in advance of the e. m. f. The deformations of the current wave are the same as are obtained with a condenser, and are due to the presence of higher harmonics.

THEORETICAL AND EXPERIMENTAL.

Dissociation of Electrolytes. The *Zeit f. Elektrochemie*, December 25th, contains a theoretical article by LIEBENOW, in which he discusses the reasons for the discrepancies in Ostwald's well-known formula for the dependency of the electrolytic conductivity of a solution upon its concentration, which formula does not always accord with the facts. As is well known, this formula is in very good agreement with the results obtained for a very large number of organic acids which are relatively only slightly dissociated. For the ordinary inorganic acids and salts which are strongly dissociated, the formula does not agree at all with the facts. Ostwald deduced his formula directly as a consequence of the law of chemical mass action. He considers that state of a solution in which y gram molecules of a salt, say potassium chloride, are dissolved in one liter of water, and in which x of these y gram molecules are dissociated into x positive potassium ions and x negative chlorine ions. There is a constant tendency of the dissociated ions to combine again and to form neutral molecules, and at the same time there exists also constantly the opposite tendency of the neutral salt molecules to dissociate into ions. There is equilibrium if both tendencies balance, *i. e.*, if the number of neutral salt molecules dissociated in a certain time into ions is equal to the number of new salt molecules formed from ions. According to the law of chemical mass action, the first number is $b(y - x)$, in which b is a constant and the second is ax^2, in which a is also a constant, hence there is equilibrium if $ax^2 = b(y - x)$. This is the basis of Ostwald's formula. The present author discusses this equation from the point of view of the theory that heat is due to irregular oscillations and movements of atoms. The left-hand part of the above equation then becomes clear. A large number of electrically-charged ions are in rapid movement in the electrolyte. If by chance a positive ion comes into a favorable position with respect to a negative one, they will unite to form a neutral molecule. It is clear that the number of such favorable positions must be proportional to the product of the concentrations of both ions, hence the term ax^2 in the above equation. The right-hand part of the equation is not as self-evident; $y - x$ is the number of neutral molecules, and if the number of such molecules which are dissociated into ions in a certain time is to be directly proportional to the number of existing molecules, it would be necessary to assume that such a dissociation is not due to a collision of a salt molecule with an ion, nor of a salt molecule with a salt molecule, but of a salt molecule with molecules of water. In order to explain this, he refers to the Nernst-Thompson rule, stating that there is in general a parallelism between the degree of dissociation and the dielectric constant of the solvent. This rule is easily explained if one assumes that the neutral salt molecules are not really electrically neutral, but that in a KCl molecule, for instance, the K atom has its positive charge and the Cl its negative charge. But the two charged atoms cling together and are not separate ions, but form a molecule which is electrically polarized. According to the ordinary laws of electrostatics, the greater the dielectric constant of the solvent the smaller is the force of attraction between both atoms, *i. e.*, the more is such a polarized salt molecule liable to be ionized if a force to that effect is acting from the outside. Now, such a force would exist if a charged ion comes into the proximity of a polarized salt molecule. The first action of the ion upon the molecule will be to exert a torsion of the molecule so that the ion comes to lie in the continuation of the axis of the polarized molecule. The attracting force of the ion upon the oppositely-charged atom of the polarized molecule is then a maximum, and a disruption of the molecule is liable to take place. This is the fundamental conception upon which the author bases his calculations. His final result is $\frac{m^2}{(1-m)v} = A + B\left(\frac{m}{v}\right)^{\frac{2}{3}}$, where A and B are constants, v is the quantity of water in which one gram molecule of salt is dissolved and m is the ratio of the molecular electrolytic conductivity to that for infinite dilution. Ostwald's final equation is a special case of the above, namely, if $B = O$. As Ostwald's final formula contains only one empirical constant and the above two, it is to be expected that the latter can be made to agree better with the facts than the former. Indeed, the author shows that for potassium chloride the difference between the calculated and the measured values is always less than 1 per cent. for a range of concentrations between 0.0001 and 3.

Phase Rule.—A long abstract is published in the *Zeit. f. Elektrochemie*, December 25th, illustrated by diagrams, of a lecture by VAN'T HOFF on Gibbs' phase rule, its application to different cases and on graphical methods for representing such chemical problems. He thinks that the very great, but mainly formal, value of the phase rule will never make it superfluous to treat problems of chemical equilibrium in accordance with molecular theories.

Action of Halogens on Alkalies.—A contribution to the theory of the action of halogens upon alkalies is given by FOERSTER and MUELLER in the *Zeit. f. Elektrochemie*, December 18th. If a zinc rod is placed in a copper sulphate solution, the reaction is $Zn + CuSO_4 = ZnSO_4 + Cu$. From the point of view of the electrolytic dissociation theory, this equation can be written $Zn + Cu^{\cdot\cdot} = Zn^{\cdot\cdot} + Cu$, where each dot represents a positive electric charge; so that the process may be expressed by stating that the zinc atoms take positive charges from the copper ions, so that the zinc atoms become ions and the copper ions become atoms (exactly the process in the Daniell cell). An analogous consideration may be applied to the action of halogens upon alkali. If this action would be exactly analogous to the above, the equation becomes $X_2 + 2KOH = 2KX + H_2O + O$, where X is a halogen. Or if we write the equations of the ions, it becomes $X_2 + 2OH^1 = 2X^1 + H_2O + O$, where the sign 1 represents a negative electric charge. It is known, however, that only fluorine behaves in this way, while for the other halogens the process is more complicated. The authors show that the process of the action of any quantity of a halogen upon any quantity of an alkali consists in the formation of two conditions of equilibrium, which are represented by the following equations:

$$X_2 + OH^1 = X^1 + XOH$$
$$XOH + OH^1 = XO^1 + H_2O.$$

The authors calculate the numerical constants which determine these equilibria and apply their theory especially to the case of the action of chlorine upon an alkali.

Spontaneous Deozonization.—If partly ozonized oxygen is left to itself, the proportion of ozone decreases with the time. This phenomenon is known under the name of spontaneous deozonization, and may be due to a variety of causes. WARBURG points out in the *Ann. d. Phys.*, November 12th, that since the amount of ozone at 200 degrees in a state of equilibrium is inappreciable, such equilibrium can be attained at ordinary temperatures only by complete dissociation of the ozone. The factors bringing about this dissociation may be external, as for instance, a contact with foreign bodies or with the walls of the vessel; or they may be internal and due to the collision of two molecules of ozone or of a molecule of ozone with a molecule of oxygen. He formulates a mathematical

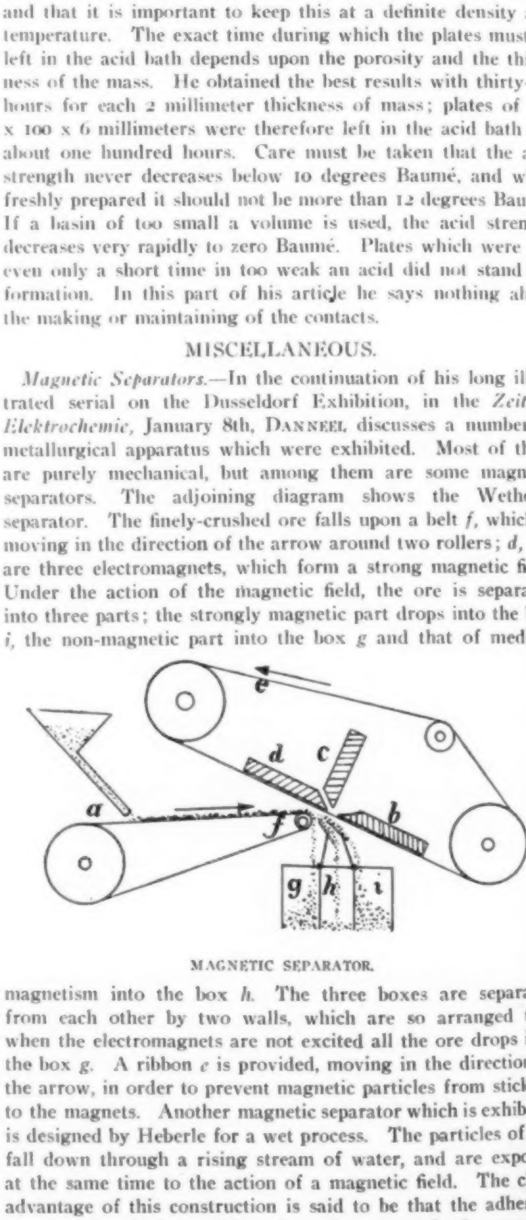
theory of the process, and finds by suitable experiments that the internal effects are almost entirely due to collisions between the ozone molecules themselves. Heat increases this internal disintegration much more rapidly than it does the external process, and it becomes the chief agent at high temperatures. He finds that moisture makes no difference to the stability of ozone at 100 degrees. An abstract may be found in the Lond. *Elec.*, January 9th.

PRIMARY AND SECONDARY BATTERIES.

Plates Made of Slabs of Active Material.—The literature on storage batteries during the past month has been scant. About the only matter of interest is an article by LEIMER, who seems to have given very much attention to the manufacture of accumulator plates made of a solid slab of material. Such plates are not new, as they were made and tested by the present writer nearly twenty years ago. The difficulty did not seem to lie so much in the making of such slabs, as there are various processes by which this can be successfully done; but it seems to lie more in making and maintaining a good contact between the slabs and the conductors or frame; also in the fragility of the slabs, as those of peroxide are very brittle and become soft in time, while those of spongy lead have at all times very little strength. This direction of development of storage-battery plates has always been a tempting one, although it does not seem to the writer to be a very promising one. However, LEIMER'S experiences may be of interest and use. The beginning of his description is given in the *Centralbl. f. Accum.*, January 1st. He claims that such plates have the advantage over those of the Planté and the Faure type, in that they have a very high capacity in a small volume and a relatively low weight, and that they are strong and light enough to be used for traction purposes; but they require very careful treatment during manufacture. Although the correct choice and use of the pasting material is of importance, yet the main point is the careful treatment of the plates themselves in all the phases of their manufacture. He has found phenole in aqueous solution to be suitable for a binding material; it forms a basic phenylate with lead oxides, while in alcoholic solutions it does not. For preparing the "solution," he mixed, in his first experiments, 1 part of the purest crystallized carbolic acid (98.8 per cent.) with 15 parts of distilled water. With this solution the minium and litharge are moistened so that they can be shaped by hand without giving off free liquid. For the positive plates, pure minium was used, but not every kind of minium is suitable. He cites a case where, out of ten different kinds, only one would answer. Sometimes a kind of minium is unsuitable, although the percentage of oxygen is high and there are no impurities. The pasting of this material into the frames must be done with great care; all places like corners must be well filled out. When the surface has been made smooth, but still has some holes or depressions, it will not do to fill them up with the mass, as it will always be found to scale off during the formation. In no case should more minium be moistened with the solution than can be used on the same day. The pasted plates should be perforated at once, and should be treated with great care before they are placed into the acid bath. To prevent the mass from sticking on the glass plates before the pasting, the frames are separated from the glass plate by a piece of wood paper. The pasted plates, after having been perforated, are placed with their surface upon a fresh piece of paper, and, with this upon a glass plate, the plates are thus placed above each other, the upper plate being also covered with paper and glass plate. In this condition the plates are left for at least twelve hours, after which they are brought into the drying oven, which is so designed that it is air-tight. During this period a pure, dry, hot stream of air passes through it, the temperature being adjustable. In the stove the plates are placed one above the other in two series, so that each plate touches the next one with the long side. The plates must be exactly perpendicular, and at a distance of at least 1 centimeter to accomplish a uniform drying process on both sides. They should stand, and not lie horizontally, while being dried. At the beginning of the drying, the temperature should not be more than 40 or 50 degrees; after twelve hours it is raised to about 120 or 150 degrees, and this temperature is kept constant for about thirty-six hours. The temperature is then decreased, and the oven is left to itself to cool. After twelve hours the plates, which then have about the temperature of the hand, are placed at once into the acid bath, which should have the same temperature. It is important that the plates should not be left in the ordinary atmospheric air, as he found that this had a bad effect upon them. When prepared by the process just described, they could not well be formed. It was found that the solution of carbolic acid, mentioned above, was too strong; therefore solutions more dilute than 1 ÷ 15 were tried, and finally he found that solutions of 2 to 5 per cent. were the best. Moreover, he found that the plates must remain in the acid bath only for a certain time, and that it is important to keep this at a definite density and temperature. The exact time during which the plates must be left in the acid bath depends upon the porosity and the thickness of the mass. He obtained the best results with thirty-six hours for each 2 millimeter thickness of mass; plates of 140 x 100 x 6 millimeters were therefore left in the acid bath for about one hundred hours. Care must be taken that the acid strength never decreases below 10 degrees Baumé, and when freshly prepared it should not be more than 12 degrees Baumé. If a basin of too small a volume is used, the acid strength decreases very rapidly to zero Baumé. Plates which were left even only a short time in too weak an acid did not stand the formation. In this part of his article he says nothing about the making or maintaining of the contacts.

MISCELLANEOUS.

Magnetic Separators.—In the continuation of his long illustrated serial on the Dusseldorf Exhibition, in the *Zeit. f. Elektrochemie,* January 8th, DANNEEL discusses a number of metallurgical apparatus which were exhibited. Most of them are purely mechanical, but among them are some magnetic separators. The adjoining diagram shows the Wetherill separator. The finely-crushed ore falls upon a belt *f*, which is moving in the direction of the arrow around two rollers; *d, c, b* are three electromagnets, which form a strong magnetic field. Under the action of the magnetic field, the ore is separated into three parts; the strongly magnetic part drops into the box *i*, the non-magnetic part into the box *g* and that of medium



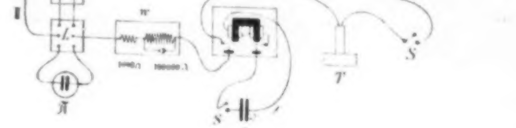
MAGNETIC SEPARATOR.

magnetism into the box *h*. The three boxes are separated from each other by two walls, which are so arranged that when the electromagnets are not excited all the ore drops into the box *g*. A ribbon *e* is provided, moving in the direction of the arrow, in order to prevent magnetic particles from sticking to the magnets. Another magnetic separator which is exhibited is designed by Heberle for a wet process. The particles of ore fall down through a rising stream of water, and are exposed at the same time to the action of a magnetic field. The chief advantage of this construction is said to be that the adhesion between the single particles of ore is so completely removed that the magnetic particles are absolutely free; that is, they are independent of the non-magnetic particles, and are thus enabled

to follow the magnetic attraction. In this way a satisfactory separation of fine powders becomes possible.

Portable Capillary Electrometer.—The capillary electrometer is of special interest to electrochemists, as it is especially adapted, in fact limited, to very low voltages; but it measures these with great precision. It is therefore convenient also for measuring the differences between two voltages, be they large or small, providing only that they are very nearly alike. In a recent (Brit.) Physical Society paper SMITH describes an instrument which is a modification of a form of capillary electrometer, consisting of two wide tubes joined by a cylindrical capillary tube, which may be horizontal or inclined. The apparatus contains mercury and sulphuric acid of about maximum conductivity, suitably distributed in the tubes. A spring key is commonly employed with such an instrument, and keeps the two platinum terminals at the same potential whenever the spring is not depressed; when depressed, the terminals are put in contact with the two points, the potentials of which are to be tested for equality. In the instrument shown by the author, the two wide tubes are sealed at the top to prevent evaporation of the sulphuric acid. The wide tubes are also joined near the top by another tube, which allows free motion of the liquids within the apparatus. With this arrangement, the instrument is made air-tight, and can, if desired, be made free of air by exhausting the apparatus before sealing. The distribution of the mercury can be altered most easily by means of a third cross piece, which is provided with a tap. To prevent the platinum wires which form the electrodes from being wetted by the acid, if the apparatus should accidentally or during transit be laid on its side or turned upside down, the lower ends of the tubes may be slightly constricted above the ends of the platinum terminals. If the terminals consist of amalgamated platinum foil, the constriction is unnecessary. If a spring key is made of brass, the contacts frequently become unsatisfactory through surface tarnishing; and if, to avoid this, the bearing surfaces are made of platinum, the key may be subject to thermo-electric effects. Such a key cannot conveniently be fastened on the same stand as the rest of the instrument, for, unless the stand and the support on which it rests are very rigid, the pressure necessary to depress the spring produces sufficient movement of the meniscus during the act of depression to render the detection of minute changes of surface tension impossible. These difficulties are overcome by using a key consisting of a U tube closed at one end, communicating at the other with a pneumatic pressure ball and containing mercury in the bend. Three platinum wires are fused into the tube, so that by squeezing the ball the same change of contacts is produced as by pressing the lever of an ordinary spring key. This form of key can be extended so that a slight pressure applied to the ball makes it work as an ordinary electrometer key, and greater pressure reverses the contacts between the terminals and the points under investigation. With such an arrangement, the sensitiveness of the instrument is doubled, and, by using a microscope magnifying 50 diameters, a P. D. of 1-10,000 volt can be detected without difficulty. The instrument, used as a surface-tension galvanometer, is more convenient than an ordinary galvanometer with a magnetic system, because there is no suspension, no lamp and scale, and practically no leveling. An abstract of his paper is given in the Lond. *Elec.*, December 26th.

Measuring Voltages with the Telephone.—The telephone has been used for a long time in Kohlrausch's method of measuring the conductivity of electrolytes, but FISCHER has recently extended its application to measuring an e. m. f. or a potential difference, which then enables him to also measure a current by determining the potential difference at the ends of a known resistance. It is based upon Poggendorf's compensation method, as may be seen from the adjoining diagram, in which *a b* is a measuring wire and *c* is a sliding contact; *E* is a battery or other source of current. Between *a* and *c* there are, on the right, the switch S, then the telephone T, an electromagnetic interrupter, a resistance of two coils of 1,000 ohms and of 100,000 ohms, the latter of which can be short-circuited, and a switch L, which enables one to put into circuit either a Weston standard cell or the e. m. f. which is to be measured. His electromagnetic interrupter, in which a vibrating spring is used, gives about 600 interruptions per second. The measurement is made after the circuit *a E b c a* has been closed for fifteen minutes. For instance, the problem may be to measure the e. m. f. of a Clark cell on the basis of the e. m. f. of the Weston cell of 1.0190 volts. By means of the switch L, the Weston cell is inserted into the circuit II, which is still open at S. The 100,000 + 1,000 ohms are inserted, and *c* is placed in the center of *a b*, say, on the division 500 if the whole scale is divided into 1,000 parts. The interrupter is then set into action, and the circuit II is closed at S. The telephone will then make a sound; the sliding contact *c* is then moved, say, to 502.0, where the telephone is silent. It starts again when *c* is on 518, hence the minimum is between 502.0 and 518.0;



MEASURING VOLTAGE WITH THE TELEPHONE.

c is then placed on 510, which is the middle point between 502.0 and 518.0, and the resistance of 100,000 ohms is short-circuited. If, by chance, 510 is the correct point, the telephone remains silent, otherwise it will sound. By an actual test, it was found to be silent between 513.4 and 513.2. The e. m. f. of the Weston cell is therefore assumed to correspond to 513.3. Now circuit II is opened, the switch L is changed so that the Clark cell is inserted instead of the Weston cell and the whole operation is repeated. The e. m. f. of the Clark cell was thus formed to correspond to 719.3 lines of scale; hence it is $\frac{719.3}{513.3} \times 1.0190 = 1.4280$ volts, the temperature being 19.1° C. The value given by the Reichsanstalt is 1.4278. For another temperature it was found 1.4379, while the Reichsanstalt gave 1.4376. The method is therefore quite exact. The weak point in the method seems to be that it is assumed that the main current in the wire is absolutely constant. This could be avoided by the lower circuit duplicated, so that two observes could measure the two e. m. f.'s simultaneously on the same potentiometer wire. The present description is taken from an article in the *Zeit. f. Elektrochemie*, January 1st.

Measuring High Temperatures.—FERY recently described a new method for measuring high temperatures, based upon the law of Stephan. According to this law, the heat transferred from a radiant body of the temperature T to another body of the temperature t is $A(T^4 - t^4)$ if both bodies have the emission capacity unity. If t^4 is small compared with T^4, the heat transferred is AT^4. According to Kerchhoff, the above condition of the emission capacity, being unity, if fulfilled for bodies inclosed on all sides. This is the case, for instance, in the electric furnace, in which the opening through which the radiation passes is sufficiently small. In the author's apparatus the radiation is concentrated by means of a lense upon a thermo-cell, and its e. m. f. is measured. A comparison of this apparatus with the pyrometer of Le Chatelier gave differences of less than 1 per cent. between 1,000° and 1,500° C., while below 900 degrees the differences were greater, on account of the smallness of the deflections of the instrument. The author determined by this method the temperature of the positive carbon of an electric arc lamp at 3,490 degrees. For very high temperatures, this method appears to be quite suit-

able. A fuller description can be found in the *Comptes Rendus,* v. 134, p. 977, and an abstract in the *Zeit. f. Elektrochemie,* November 20th.

CURRENT NOTES.

American Electrochemical Society.—At the meeting of the Board of Directors, held at Philadelphia, Pa., on January 8th, the following new members were elected: Theron C. Stearns, Jersey City, N. J.; Abraham Van Winkle, Newark, N. J.; Prof. Chas. F. Chandler, New York; Dr. G. Drobegg, New York; Alfred Stansfield, Montreal, Canada; Dr. Victor Goldschmidt, Heidelberg, Germany; Dr. H. W. Wiley, Washington, D. C.; Samuel B. Devlin, New York; Joseph Wetzler, New York; Walter M. Stein, Prismos, Pa.; Dr. Charles Kellner, Vienna, Austria; Dr. Richard Hammerschmidt, Frankfurt a. M., Germany.

At the meeting of the Board of Directors on February 5th the following new members were elected: L. Seeger, New York; Dr. Rud. de Neufville, Frankfurt a. M., Germany; Dr. Hans Landolt, Turgi, Switzerland; J. M. Morehead, Chicago, Ill.; Wm. Smith Horry, Niagara Falls, N. Y.; C. I. Zimmerman, Madison, Wis.; John W. Schlegel, New York; Craig R. Arnold, Sharon Hill, Pa.; A. J. Rodgers, Milwaukee, Wis.; O. M. Thowless, Newark, N. J.; Godfrey L. Cabot, Boston, Mass.; Joseph B. Hall, Chicago, Ill.; Francis W. Higgins, Niagara Falls, N. Y.; Robert S. Allyn, New York; Ralph McNeill, New York; Takakichi Nakayama, Kochi, Japan.

The annual meeting of the American Institute of Electrical Engineers will be held in June, at Niagara Falls. It was found impracticable to arrange a joint meeting of the American Institute of Electrical Engineers and of the American Electrochemical Society in the autumn at Sault Ste. Marie.

Water-power in Norway.—According to a report from Christiana, the Rjukanfoss, in Telemar, known as the Norwegian Niagara, has been sold to a Swedish industrial trust, which will develop its power.

Stevens Institute of Technology.—Mr. Alexander C. Humphreys was formally inaugurated as president of this institute on February 5th.

St. Louis World's Fair.—It is announced that the grounds and buildings will be dedicated on April 30th by the President of the United States, and an address will be delivered by ex-President Grover Cleveland.

Wellesley College is to have, through the generosity of Mr. John D. Rockefeller, an entirely new and up-to-date power plant. Apparatus will be installed for heating all the buildings on the college grounds, which extend over several acres, and the grounds will be lighted by electricity throughout. Electric motors also will be used for operating elevators and blowers for ventilation purposes. Mr. Rockefeller has recently purchased from the Westinghouse Electric and Mfg. Co. for this plant two alternating-current, engine type, two-phase alternators, separately excited, one of 150 kilowatts and one of 75 kilowatts; also a five-panel switchboard.

Book Reviews.

The Electro-Plating and Electro-Refining of Metals. By Arnold Philip. London: Crosby Lockwood & Son; New York: D. Van Nostrand Co. 680 pages. Price, $4.50.

This volume is a new edition of a well-known work, being in the main a reproduction of the last edition of Watt's "Electrodeposition." Chapters on electrometallurgical operations, including the electrorefining of copper, gold, silver, lead and nickel, treatment of tin, production of aluminium, and electrogalvanizing have been added with the view of bringing the work to date.

The book has its chief value in its historical treatment of questions relating to the deposition of metals, and covers quite extensively the field of electroplating in referring to the workshop details of various operations connected with the treatment of metal surfaces.

In the preface, the author expresses a hope that his guiding principle of neglecting theory, except in the most superficial and sketchy manner, will be apparent. This hope can undoubtedly be realized, as not only is theory neglected, but even such well-established laws as those of Faraday, the basis of electrochemical calculations, are not even stated or used as guiding principles in the discussing of various processes. The author excuses this neglect by stating that "a technical text-book cannot and should not deal with explanations of underlying theory, but should assume them." Even should those desiring a text-book on this subject agree with the author on this point, an examination of this book may cause some wonder as to what underlying principles warrant certain statements, such as that on page 498, where it is claimed that the construction of dynamo machines used for copper refining "should undoubtedly be based upon the quality of copper which it is intended to refine by their agency. A dynamo which would fulfill all the requirements of electrolysis of one variety of copper would be unsuited for refining metal of higher resistance."

While we cannot overlook the many good features of Watt's book on electroplating it is difficult, in this day of more advanced electrochemical practice, to find justification for perpetuating statements such as the following which appear in the pages of this new edition. On page 487 a statement, that doubt may be cast upon certain laboratory tests, inasmuch as the current for making them was furnished by voltaic batteries, whereas dynamo current is used in practice, and on pages 313 and 334, that a satisfactory plating can be obtained in about one-half the time with dynamo current than it can with battery current, might convey the impression that current derived from a battery differs very materially in its electrolytic effects from that delivered by a dynamo.

While this work gives a large number of recipes for solutions, describes processes and operations used in connection with the treatment of metal surfaces and contains a fund of information useful to the plater, the instruction as far as it relates to electroplating practice, is decidedly of the rule-of-thumb order. There are few progressive platers, in this country at least, who would find in this book a satisfactory guide in their work. The amperemeter is mentioned and illustrated in the early part of the book, but its use is hardly referred to throughout the part on electroplating. The effect of current density on character of deposit is not treated, nor are data for proper current density for various metals and solutions given. Information relating to current strength is occasionally lightly touched upon by phraseology, such as "a battery power of three or four pairs is required."

The modern plater is rapidly leaving the rule-of-thumb methods which characterized earlier plating work; he is being guided by theory and classified knowledge, and employing instruments which enable him to calculate and regulate his work to a considerable degree of precision. In using this book, which neglects such guiding principles, he may naturally feel that it is out of date, or written for the amateur rather than the practical man, when, as on page 297, he is advised to carry on the "dipping" operation near a fire-place or in the outer yard. He may also recognize a touch of humor on page 295 where, in describing the operation of the hot lye vat used for cleaning, it reads: "It is easy to ascertain if the potash has lost its caustic property by dipping the tip of the finger in the solution and applying it to the tongue." The positiveness of this method of testing is not a sufficient reason for recommending the tongue as a testing agent, especially where potassium cyanide is made free use of, as it is in many plating establishments.

The first two chapters of the book are new, replacing chapters I, II, III and V of the old book. They deal with the various sources and generators of electrical energy. It may

strike the reader as peculiar that as much space is given to description of the thermo pile, an apparatus which has never become of much practical importance, as is given to the dynamo. The author says that "there is only one form of dynamo which is of any practical use for the electro-metallurgist, and that is the particular form of machine known as the shunt dynamo." This statement could hardly have been made with a full knowledge of the advantages of compounding and of the compound-wound machines which are being installed in many plating establishments in preference to shunt-wound dynamos.

The last 200 pages constitutes new matter added to the former work on electroplating. An admirable feature introduced here and one which is not often found in electrochemical books is the extensive treatment of the problem of copper refining from the financial or commercial standpoint. The author calculates the most economical current density, which is shown to depend upon various factors, such as cost of power, labor and rate of interest. He states that a similar line of reasoning may apply in calculation of processes of refining metals other than copper. While this is perhaps the best treatment of the problem which has been published, it is not entirely satisfactory. The counter-electromotive force of polarization which enters as a component of the electromotive force necessary for each tank is not mentioned, though it may play an important part. An item which enters largely in the cost of electrolytic refining of copper, and to a much greater degree in the case of other metals, is the cost of maintaining the solution in constant working condition, either by purifying or regenerating, or by making up new solution from time to time. This has not been included in the estimate of the cost of copper refining.

The new material added by the author has not the same fault of omitting the important working details such as current density and pressure as has the material taken from Watt's book. In the discussion of various processes, references are made to the leading literature on the subject. The author has been handicapped by limit of space for description of various processes and operations and the descriptions are thus somewhat incomplete and superficial. The last chapter, entitled "Electrogalvanizing," describes at length the Cowper Coles process of electrolytically depositing zinc upon iron, where insoluble electrodes are used. He does not mention, however, the processes used most exclusively in this country, which employ soluble anodes.

MONOGRAPHIEN UEBER ANGEWANDTE ELEKTROCHEMIE. Vol V: Die Herstellung von Metallgegenständen auf elektrolytischem Wege und die Elektrogravüre. By Dr. W. Pfanhauser. Halle: W. Knapp. Illustrated. Price, Marks 7.

The author is a manufacturer of machinery, apparatus and chemicals for electroplaters' use, and has thus been kept in touch with the practical side of the subject. He is also a theoretical man, and has written numerous articles for the European technical press. It is therefore not surprising to find in this book a good welding of the theoretical and practical.

The author first gives a brief review of the history of the various attempts to make metal articles by electrochemical means, and then proceeds with a clear, logical exposition of the chemical and electrochemical characteristics of the copper-plating bath. Numerous experimental facts are given, and the explanation of the formation of poor and irregular deposits is strictly scientific. The same phenomenon which has thrown so much light on the working of the lead accumulator—concentration changes in the electrolyte—plays here an equally important *rôle*. For instance, on page 8 it is stated that after seven hours of electrolysis the copper sulphate at bottom of vat was twice as concentrated as at the top. This fact was recognized some years ago by American electrolytic copper refiners. Improvements in the circulation of the electrolyte of the refinery has allowed them to use an increased current density.

The next chapter, on the physical properties of electrodeposited copper, is very good, but this is a matter which has not yet been brought to a satisfactory basis.

The latter part of the book is taken up with the various processes for making metallic powders, foil, wire, pipes, thick sheets, etc.

There has been a vast amount of money spent in attempts to electrodeposit copper wire, because cathode copper has a conductivity some 2 to 4 per cent. higher than the same copper when cast from the "refining furnace." These attempts have met as yet with only failure. The Elmore process, it is true, has been brought to a practical producing stage, but its success has been in making pipes and not in making wire.

Another successful application of the electrodeposition of metals has been the manufacture of parabolic reflectors by Cowper-Coles.

In this country seamless copper floats for water tanks are made and some types of switches are electroplated, of which we find no mention in this book. Electroplating might be properly included, but it may be supposed that this other similar process will be treated in another monograph of the series.

It is quite noticeable that the average inventor has an ingenious disregard for commercial conditions. For instance, on page 74 is noted an invention for the direct production of wire. The imaginary cost sheet of the imaginary plant shows a profit of 28,670 marks, corresponding to a profit of 28 per cent. on the capital. Of this, 28,000 marks is due to gold and silver recovered from the anode slimes. These metals are, of course, paid for by any purchaser of "converter bars," and could be of little source of profit except as competing with the electrolytic refiners. There are on our Atlantic Coast half a dozen electrolytic plants in which copper can be refined from "anode to cathode," at a cost of from $3 to $5 per ton.

The last two chapters of the book treat of electrolytic etching and Rieder's electro-engraving process.

PRACTICAL PLATING AND POLISHING. New York: Zucker, Levett & Loeb Co. 114 pages, illustrated. Price, $0.80.

This small book is intended for the use of the practical electroplater. No attempt is made to give theoretical discussions or explanations, but the book is practical in every detail.

After an explanation of the most fundamental terms of electricity, directions are given for setting up and arranging the various apparatus of a plating plant. Then follow special chapters on nickel plating, copper plating, bronze plating, brass plating, silver plating, gold plating, tin plating and galvanoplating. The rules given are worded in concise and simple language, and technical terms are avoided as much as possible, evidently under the supposition that the average electroplater is neither a chemist nor an electrician.

ELECTRIC GENERATORS FOR CHEMICAL PLANTS.

The increasing use of the electric current in chemical plants involves the question of proper generation of power. There are many factors deciding the location of an industry of this character, and it is not to be expected that all of them can center themselves about a source of energy such as we have in Niagara Falls. It therefore devolves upon the majority to generate their own power with the best means at hand. The prominent method is the use of a steam engine driving a direct-current generator.

The requirements of electrolytic work are a large current at a low voltage. It is possible, however, to so assemble the various tanks or process units that by placing a number in series we can prevent the use of generators of such an extremely low voltage as is called for in the electrochemical process. There are certain elements in the operation of the tanks or vats, however, which render it inadvisable to place too

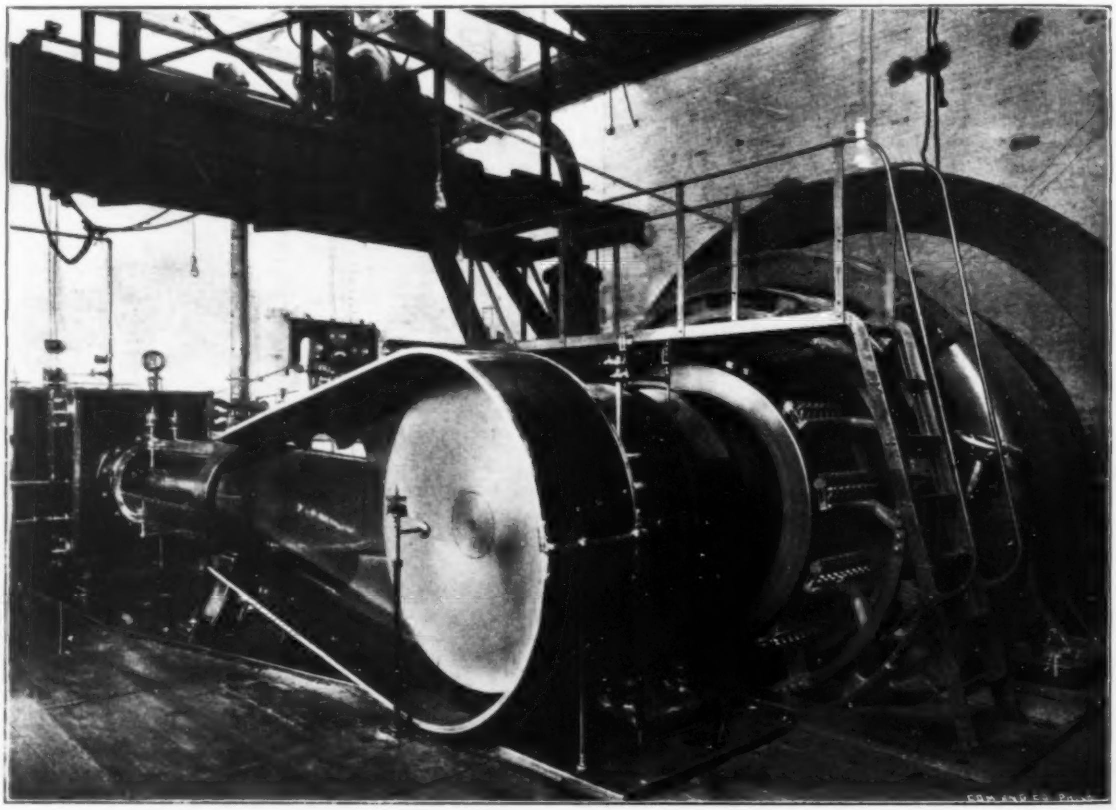
many units in series, and the result is the use of generators ranging from about 70 to 125 volts.

It is the heavy current capacity, however, which specializes the generator used for electrochemical purposes, and the services of such a machine calls for the very best in electrical design and construction. The conductors must be amply large to carry the current imposed; the commutator must be of greater size than usual, and all ventilation possible given to the windings and commutator face. The brushes must be of sufficient size and a strong and satisfactory method supplied for transmitting the current from the brushes to the cables at the generator terminals.

The machine will be called upon for practically continuous operation, and abundant opportunity furnished for the observance of its durability and action under the constant full load. It is by the recognition of these facts that a manufacturing firm succeeds in the application of their generators to work of this character. The Crocker-Wheeler Co., Ampere, N. J., have frequently had occasion to apply their standard types of generator to the special work entailed in electrolytic service.

The photograph shown above is a portion of the plant of the Balbach Smelting and Refining Co., Newark, N. J. The cross compound Corliss condensing engines made by the Hewes & Phillips Co. are direct connected to a Crocker-Wheeler generator, furnishing 4,300 ampères at a pressure of 70 volts. The current is used principally in the electric refining of copper, for which this company have been prominently known for years. A smaller portion of the current is used in that part of the plant devoted to the refining of gold, silver and lead. Upon the gallery in the background of the cut is shown a dynamo, belt-driven from the large engine below, and furnishing current at 125 volts for the driving of the power motors and lights used about the works.

The main generating unit is interesting as being typical of this type of machine, with its large commutator face and high current output in proportion to the size of the generator. Other prominent electrolytic plants using Crocker-Wheeler generators are the Buffalo Smelting Works, Buffalo, N. Y.; the Perth Amboy plant of the American Smelting and Refining Co., and the De Lamar Copper Refining Works, Carteret, N. J., representing over 3,000 kilowatts of power.



PLANT OF THE BALBACH SMELTING AND REFINING CO.

AN ELECTRIC PROCESS FOR PURIFYING WATER.

Electrochemical work, as applied to the purification of water, is the result of adapting well-known laboratory experiments to industrial practice on a large scale. We recently inspected a plant designed for this purpose and exhibited at the office of the American Electric Improvement Co., Philadelphia, Pa. While this is only an exhibit plant, the company state that the process, which is based upon patents of Mr. C. C. Clark, has passed the experimental stage, and that they are now filling orders for industrial plants.

The adjoining illustration, Fig. 1, shows diagramatically the construction of the apparatus, the whole length of which is 10 feet. While at first sight the diagram may look somewhat complicated, the construction is really very simple, and may be easily understood; 26 is the water inlet and 52 the water outlet. The water, having entered the apparatus through 26, passes into the electric chamber, containing a series of electrodes 29 and 30. There is always a negative electrode following a positive electrode, and *vice versa,* the positive electrodes being marked 29 and the negative ones 30 in the diagram. Connections of the electrodes with the positive and negative pole of the current supply are made by the wires 32 and 33, which pass through the cover of this box and are connected with the electrodes in the manner shown in the diagram.

The voltage used in the plant visited is 240 direct current. The electrodes are perforated, as shown in Figs. 3 and 4

While the water passes downward through holes 31 decomposition of the foreign substances takes place, and the mixture thus produced of purified water and of the products of the electrochemical decomposition leaves the electric chamber through the hole 42 in the bottom, and then enters the large and long cylinder 7.

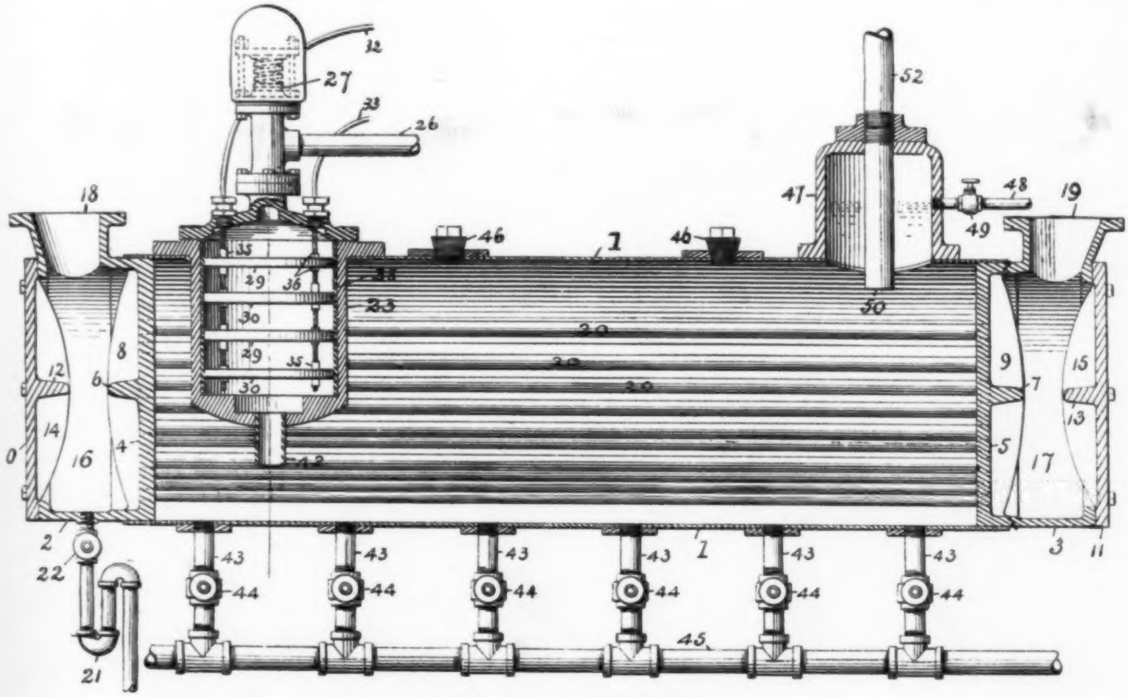
While the water inlet 26 has a small diameter, this cylinder has a large diameter, the object being to produce a relatively low speed of flowing through the cylinder with the large diameter, in order to enable those products of decomposition which have a higher density than water to settle down, and those which are lighter, such as the gases developed, to raise upwards to the top of the cylinder.

The principle of the apparatus is therefore to first decompose the impurities in the water in the electric chamber, and, second, to remove afterwards these impurities by purely mechanical means in the large cylinder; 44 are the blow-off pipes for discharging the heavier impurities. In the plant visited a dark through the tubes 20, generally exhaust steam. A drain pipe 21 connects to the bottom of chamber 16, and valve 22 opens and closes the pipe, and is only used to take away the water of condensation when the apparatus is using steam.

26 is the inlet pipe for the inflowing liquid to be treated, and above it is located a suitable relief valve 27, having means to relieve any excess of pressure above a fixed limit.

The electric chamber 23 has an insulated lining 28. The method of suspension of the positive and negative electrodes 29 and 30 is best seen in Fig. 3. The current conductors 32 and 33 are provided with insulation 35 and with conducting nuts 36. At the sides of the cover 24 are insulated stuffing boxes 37, the patented construction of which is best seen in Fig. 5.

The heavy impurities which settle down at the bottom of the cylinder can at any time be drawn off through the pipes 43, controlled by the valves 44 and connected to the discharge pipe 45. When a thorough cleaning is necessary, the wash-



APPARATUS FOR PURIFYING WATER.

brown muddy liquid, nearly solid, was discharged through them. The gases which are developed are left off through 48. The water thus freed from its impurities is led off through the outlet 52.

The inventor states that various materials have been found to be suitable for the electrodes, but that he has obtained his best results with copper and Acheson graphite electrodes. It is claimed that the wear and tear of the electrodes is small.

We may now describe the details of the apparatus. Referring to Fig. 1, the cylinder 1 is a close and tight receptacle, into the ends of which are secured circular heads having outer cylindrical rings 2, 3; inner plates 4, 5, which form tube sheets, with stiffening ribs 6, 7, 8, 9, removable covers 10, 11, with ribs 12, 13, 14, 15, so that circulating chambers 16, 17 are formed, having openings 18, 19, to which may be attached the necessary pipes to convey cooling water or steam into or out of chambers 16 and 17.

The tubes 20 extend from tube sheet 4 to tube sheet 5, their ends being secured in expansion stuffing boxes. Cold water is passed through these tubes for artificial cooling when salt water or other liquids of a high conductivity are electrolyzed. When used as a feed-water heater and purifier, steam is passed out plugs 46, at the top of the cylinder, may be removed, giving access for the introduction of a hose.

In the dome 47 the light, floating impurities are gathered, which may be drawn off by the pipe 48, controlled by valve 49, while the outflow pipe 50, for the purified water, descends below the dome and into the cylinder to the body of pure water.

The action of the apparatus is continuous during the supply of liquid and electric current, and when once set in operation it is automatic, in so far as the electric current (furnished from ordinary constant potential mains, as for lighting, etc.) will vary according to the conductivity of the liquid to be treated, *i. e.*, the less impurities are in the water the greater its resistance and the smaller the current.

Fig. 2 is a cross section of the inlet chamber. Fig. 3 shows plainly the construction of the inlet chamber, and Fig. 4 is a plain view of the electrodes.

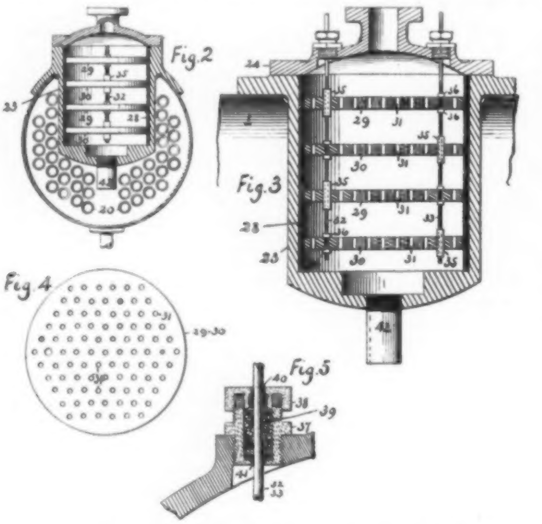
The apparatus is claimed to be suitable for a great many industrial purposes, the most important one being probably for the supply of pure water for boilers. Other applications are said to be the purifying of the water pumped from mines so that it may be used for commercial purposes; the changing of

sea water to fresh water for use on steamers; the purifying of water for manufacturing purposes, ice plants, hotels, office buildings, the purifying of sewage, etc.

The main point is, of course, the question of cost, and the inventor claims that in this respect his process is far superior to all other methods of purifying or distilling water. For an average price of electric energy (based upon the cost of generating electric energy by means of Corliss high-pressure engines, with a price of $2.50 for coal) he states that, according to a calculation made by an electrical expert, 360 gallons of fresh water can be purified at a cost of one cent by his process. This cost can still be considerably diminished if the most improved and most economical methods of power generation are applied, as found in modern power plants.

The cost for attendance is, of course, very small, as all the attendant has to do is to discharge the pipes 44 and 49 at intervals. There is no complicated device on the apparatus which might be liable to be destroyed by the carelessness of the attendant.

Another interesting application to which the apparatus is said to be well adapted is the purification and aging of alcoholic liquids. The liquor, after the treatment, is found to be pure. It is said that by this system whiskey direct from



DETAILS OF APPARATUS FOR PURIFYING WATER.

the distillery can be aged at a cost of 1½ cents per gallon, and that, after having been treated in the apparatus and stored in a charred barrel for thirty days, it is found to be equal to the best whiskey in the market. This method should therefore represent a great saving over present methods in the expenses for storing, interest and insurance. The apparatus used for this purpose contains a filter near the outlet, in order to remove impurities which have the same specific gravity as the liquor, and which therefore do not settle down or raise up in the large cylinder. Otherwise the apparatus is the same as that for purifying water.

ELECTROPLATING DYNAMOS.

The building of a dynamo for electroplating or any low-voltage work involves difficulties not encountered in ordinary machine design. Of course, the two great problems to be met lie in taking care of the heavy current without undue heating, both in the windings and at the commutator, and in the prevention of destructive sparking at the brushes. In other words, commutating the relatively large amount of current. Scientific design will avail nothing in this branch of the work without a generous allowance of iron and copper.

The Holtzer-Cabot Electric Co., Boston, Mass., are manufacturing a line of machines designed especially for work of electrochemical nature. A cut of one of the machines is shown herewith, the machine in question being capable of delivering 700 ampères at 6 volts. It will be noted that the machine is quite compact, this being necessary to ensure short, massive magnetic circuits, giving economy of exciting energy. These machines are made in two, four, six or eight-pole designs, according to the size. The armature is shown in Fig. 2. The coils are arranged cylindrically around the armature, and are made of heavy copper bars, the length being just great enough to enable a loop of the proper span to be formed. An exceedingly important feature in machines of this kind is the armature resistance, which is quite low in these machines, owing to shortness of the circuits. The windings are so

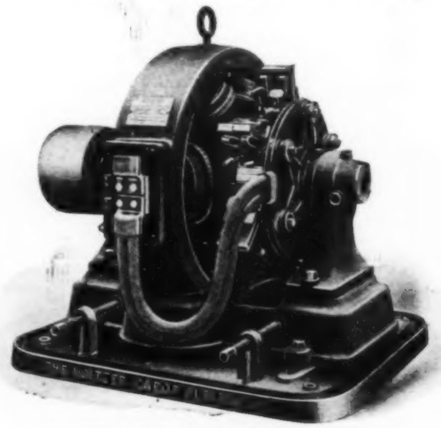


FIG. 1.—ELECTROPLATING DYNAMO.

arranged that the air may circulate freely through the conductors for ventilating purposes, which is also important. The arrangement of the armature conductors is such that, in case of injury, a coil may be replaced by simply lifting a few of the adjacent coils, it being unnecessary to strip the armature, as would be the case in many forms of windings.

The commutator is necessarily of heavy construction, with sufficient copper to make the current density very low, leaving a wide allowance for frictional heat due to the unusual area of brush surface. These segments are of pure copper, rolled to increase their density, thereby giving greater conductivity and lengthening the life of the commutator. The brush holders

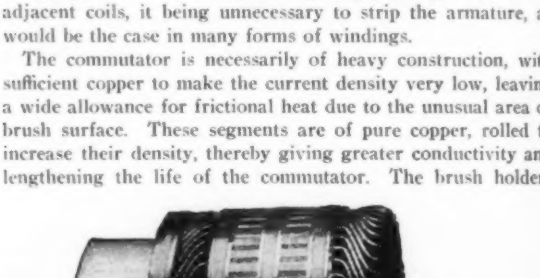


FIG. 2.—ARMATURE.

are of the tangent type, and are made especially for the carrying of heavy current. The spring is flat and loop-shaped, and is long and heavy, allowing extremely delicate adjustment, so that the brushes are held upon the commutator with a firm pressure, but without causing undue frictional heat. Provision is made for carrying the current from the brush itself to the portion of the holder which clamps the stud, so that the spring or sliding contacts are not depended on to carry current. The pedestals are so arranged that upon occasion the armature may be removed without disturbing the connections, it being simply necessary to raise the brushes and slide off the front or rear pedestal, carrying it out of the way in order that the armature may be removed. Compound winding is usually employed.

On larger machines it is often necessary to employ a double

commutator. Fig. 3 shows a machine of this kind, built by the Holtzer-Cabot Electric Co., for delivering 4,000 ampères at 6 volts. This machine is intended primarily for the electrolytic reduction of copper ore, but is, of course, suitable for any work requiring a large quantity of current at a low voltage. In this machine the poles are eight in number, and are of wrought iron, cast welded into the ring. The poles are fitted with a special form of shoe, which is of such a shape as to pre-

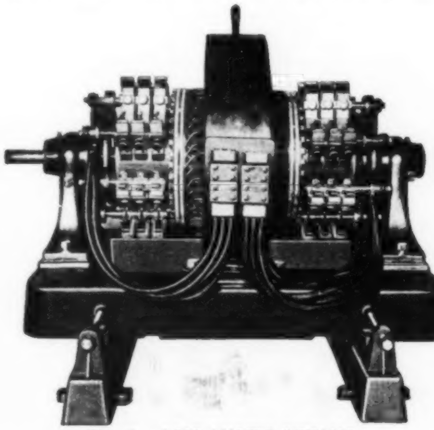


FIG. 3.—4,000-AMPERE DYNAMO.

vent the field flux from being distorted by the back magnetization of the armature. Thus the diameter of commutation remains constant, and it is not necessary to shift the brushes with changes of the load. The armature for this machine is assembled on a spider, provision being made for circulation of the air through the inner parts of the machine and out through the winding. On all these low-voltage dynamos the speed is made purposely quite low to reduce friction as much as possible and secure cool and efficient operation.

Personal.

DR. J. J. THOMSON, of Cambridge University, England, has been appointed head of the department of physics of Columbia University, New York City, to succeed the late Ogden Nicholas Rood. Prof. Thomson was born in 1856, and is best known by his famous researches made in recent years on corpuscles or "masses smaller than atoms."

MR. CRAIG R. ARNOLD, of Philadelphia, is going to the South, and to Mexico, to report on the application of electrolytic gold processes to certain mines.

MR. J. WALTER WELL has resigned the position of Provincial Assayer for Ontario, in order to specialize along certain lines affecting the mining industry in Ontario. Mr. A. G. Burrows has been appointed to succeed him.

MR. ANDREW CARNEGIE has notified the Provost of Greenock, Scotland, that he is prepared to give $50,000 to erect a memorial to James Watt, the inventor, who was born in that city on January 19, 1736, in recognition of his engineering achievements; or he will head a movement in America to raise a large fund which, in conjunction with sums raised in Great Britain, will provide for a more extensive scheme of commemoration.

COUNT CORRADO EMO-CAPODILISTA, of Milan, Italy, was recently in the United States for the purpose of making a study of the electrical and electrochemical industries as developed here.

MR. GEORGE H. GIBSON has resigned his position with the Westinghouse Co's publishing department, Pittsburg, Pa., to accept a position with the B. F. Sturtevant Co., Jamaica Plain Station, Boston, Mass., the well-known manufacturers of blowers, heating, ventilating and forced-draft apparatus, electrical machinery and steam engines. Mr. Gibson was formerly a member of the editorial staff of the *Engineering News*, of New York City, and is a graduate of the Engineering School of the University of Michigan.

OBITUARY.

We regret to report the death of MR. A. T. WEIGHTMAN, who was well known among the electrochemical fraternity of this country as the electrochemist to the Electrical Lead Reduction Co., Niagara Falls, N. Y. Owing to failing health, he recently resigned this position and went to England to recuperate. He died in London, on February 3d. He was a member of the American Electrochemical Society, and at the Niagara Falls meeting he read a paper on the scientific principles of the Salom lead-reduction process.

INDUSTRIAL NOTES.

THE OHIO BRASS CO. have decided to substitute alternating-current power distribution for the direct-current system at present in use in their shops at Mansfield, Ohio. A recent purchase from the Westinghouse Electric and Mfg. Co. comprises a 180-kilowatt, 7,200 alternation, two-phase alternator, a direct-current exciter, switchboard equipment and the following induction motors: two of 40 horse-power, four of 30 horse-power, one of 20 horse-power, one of 15 horse-power and one of 2 horse-power. The alternating-current motors have been chosen on account of their low cost of maintenance and freedom from break-down.

THE SUSQUEHANNA IRON AND STEEL CO., Columbia, Pa., are about to install an electric-power distribution plant in their mills. A recent purchase from the Westinghouse Electric and Mfg. Co. comprises a 400-kilowatt alternating-current generator, one 200 horse-power induction motor and 300 to 400 horse-power in motors, ranging in size from 50 to 20 horse-power.

THE AMERICAN ELECTRIC IMPROVEMENT CO., Philadelphia, Pa., are installing a water-purifying plant for the T. A. Harris Co., Continental Dye Works, Philadelphia, Pa.

THE ANACONDA COPPER MINING CO. are about to put in operation a new 5,000-ton-per-day reduction plant, which will be equipped with electrical apparatus for power distribution. A recent contract with the Westinghouse Electric and Mfg. Co. embraces seven motors, of an aggregate of 185 horse-power, to be added to the present installation of about 30 Westinghouse motors, of an aggregate of over 1,000 horse-power.

THE ST. JOSEPH AND ELKHART POWER CO., Mishawaka, Ind., are installing a large hydraulic plant on the St. Joseph River, near Mishawaka, including power house, dam and hydraulic and electric equipment, for the generation and transmission of electric power to the cities of South Bend, Mishawaka and Elkhart, Ind., and adjacent territory. The energy will be used for general lighting and power purposes. The consulting engineers and general contractors for the complete development are Sanderson & Porter, 31 Nassau street, New York City, who have recently purchased from the Westinghouse Electric and Mfg. Co. four 1,000-kilowatt, 13,200-volt, revolving-field alternators and two 125-kilowatt, direct-current exciters. The machines are all to be direct-coupled to horizontal-shaft water wheels.

TRADE CATALOGUES.—We have received trade catalogues from the following companies: Fort Wayne Electric Works, Bulletins 1,037 and 1,038 (Mast arms. The B. & B. commutator touring device) and flyers 4,040 and 4,041 (Primary fuse boxes. Type a transformer "strikes"). Fred. M. Locke, Victor, N. Y. (Victor insulators). Alphaduct Mfg. Co., New York (Alphaduct flexible conduit). Alberene Stone Co., New York (Alberine stone fo· use in high potential work). Crouse-Hinds Electric Co., Syracuse, N. Y. (Norbitt porcelain electrical appliances).

THE MATLACK PLATINUM WORKS, Sugartown, Pa., owned by J. Bishop & Co., were recently destroyed by fire, which was started by burglars.

THE MEXICO MINE AND SMELTER SUPPLY CO., Mexico City, Mexico, have recently ordered several centrifugal pumps from the Morris Machine Works, New York, N. Y.

DIGEST OF U. S. PATENTS PRIOR TO JULY, 1902.

Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.

This digest of electrochemical United States patents prior to July, 1902, will be one by classes, setting out for comparison in each class those devices which have the same object, or those methods which seek the same results. In each class the patents will be arranged chronologically. The digest will be complete in the sense of covering every point which is touched upon in the original specification.

(Continued from page 196.)

518,710. Henry Carmichael, Malden, Mass., April 24, 1894.

Rectangular vessel has sides of glass or slate and trough-shaped bottom of iron, with vertical parallel ribs, serving as cathode. Anode compartment, a rectangular box having a trough-shaped bottom of asbestos, stiffened with hydraulic cement, resting on cathode ribs. Sides of vessel extend up around sides of anode compartment, and serve to collect hydrogen. Some of the cathode ribs extend up into the hydrogen-collecting chambers. Anode, lumps of gas carbon or magnetite, supported on a net of platinum wires carried by platinum pegs, which pass into an insulated frame and conductor of heavy copper wire. Gradually feeds brine into cell through perforated pipes opening upwardly against anode, thus washing it and maintaining a zone of brine between anode and cathode. May suspend basket of salt in anode compartment. Cathode ribs direct caustic to middle of bottom, along which it flows, increasing in concentration, to an outlet at one end. A siphon delivers caustic in drops through a layer of petroleum, preventing short circuit and excluding air. Caustic diffusing through diaphragm conducted back by a horizontal pipe lying on diaphragm, and opening through it into cathode compartment at end remote from outlet. Inflow of brine proportioned to outflow of caustic, and causes downward movement in anode compartment, hindering upward diffusion of caustic. Increases difference of specific gravity of anode and cathode solutions by surrounding anode compartment with lagging to retain heat, while iron base and ribs conduct away heat. Base may also have external corrugations. Delivers a broken stream of brine to the feed pipe by a rotating scoop. Shows a plurality of cells electrically connected in series, with common supply and discharge pipes.

A second form of apparatus employs a circular glass bell and iron base, between which is clamped a conical diaphragm, delivering the hydrogen to a central collecting chamber. Radial cathode ribs on the base form a tortuous passage, delivering caustic to a central outlet. Pipes for supplying brine and delivering chlorine and hydrogen pass through base. Cathode ribs may extend upwardly into hydrogen chamber.

A third form of apparatus for electrolyzing sodium sulphate, similar to second form, but has side outlet for sulphuric acid.

522,615. Isaiah L. Roberts, Brooklyn, N. Y., July 10, 1894.

Vessel, a U-shaped glass tube, with central supply pipe. Salt fills pipe and bend of tube, serving as diaphragm. Anode, limb of U tube filled with broken coke or charcoal, receiving a carbon rod conductor; iron cathode in other limb. Caustic outlet in bend. Modification, using rectangular vessel, divided transversely by a narrow, perforated box of glass or stoneware, filled with salt. Anode compartment filled with broken carbon.

522,616. Isaiah L. Roberts, Brooklyn, N. Y., July 10, 1894.

Iron vessel, serving as cathode. Diaphragm, a bag of wire netting and cloth or asbestos, within which is a perforated or porous jar of unglazed porcelain, the space between being filled with sand or powdered anthracite. Porous jar filled with salt, into which depends the charcoal anode. Cell closed at top by wood or tile, soaked in paraffine and wax. Glass ring insulates diaphragm from iron vessel. May use tubular charcoal anode, receiving a perforated salt-supply pipe.

522,617. Isaiah L. Roberts, Brooklyn, N. Y., July 10, 1894.

Similar to preceding, but has drain pipe from anode compartment to remove such impurities as sulphuric acid and chlorides or sulphate of aluminium, iron and calcium.

522,618. Isaiah L. Roberts, Brooklyn, N. Y., July 10, 1894.

Same as 522,616.

525,732. September 11, 1894; Emile Andreoli, London, England.

A series of narrow anode and cathode compartments are separated by diaphragms of porcelain, made of powdered pumice and asbestos or infusorial earth. The anodes may be of metal, *e. g.*, iron, peroxidized lead or platinum, or of retort carbon, ground flat on side facing cathode. Anodes have necks passing through holes in a slate cover, a tight joint being made by a cement of ground asbestos, porcelain and litharge, and by a winding of paraffined string. A system of pipes gives a forced circulation through all the compartments of each cell and through several cells in succession.

534,033. February 12, 1895; Thomas Craney, Detroit, Mich.

Evaporates caustic soda solution in cast-iron kettles, and passes an electric current from a carbon anode to each kettle to purify solution. Current converts metallic oxides dissolved from metal of kettles into insoluble higher oxides, which settle out.

541,146. June 18, 1895; Henry Blackman, New York, N. Y.

Returns brine to cell, after saturating and cooling it. Cooling pipes pass through cell. Shows various cells, one containing a series of alternating plate electrodes of platinum and zinc.

549,186. November 5, 1895; Thomas Craney, Bay City, Mich.

Anode compartment, a vessel of perforated metal or wire cloth, serving as cathode, lined with asbestos. Sides have an insulating lining. A body of broken carbon rests on the asbestos and serves as anode, contact being made by protected carbon pencils depending into it. Outer vessel of iron, which may also act as cathode. Pipes lead to and from anode and cathode compartments.

552,895. January 14, 1896; Thomas Craney, Bay City, Mich.

System employing a tandem series of the cells shown in patent 520,257. Pipes connect anode and cathode compartments respectively. Anode solution from last cell freed from chlorine and returned. Caustic solution from last cell falls through a carbonating tower, and may be converted into either normal or acid carbonate. If normal carbonate, it dissolves, heat being used if necessary, but is partially precipitated in a cooling tower, the residual solution returning to cathode compartment of first cell. Bicarbonate precipitates partly in carbonating tower and partly in cooling tower. Conveyer removes carbonate to a draining bin.

552,955. January 14, 1896; Thomas Craney, Bay City, Mich.

Solution from last cell descends through a high stand pipe against a rising stream of carbon dioxide. Bicarbonate removed from bottom, partially dried in a centrifugal, fully dried by a mixture of hot air and carbon dioxide, and ground. May wash out any traces of salt by a bicarbonate solution thrown into centrifugal. Residual monocarbonate solution from a stand pipe returned to cathode compartment of first cell.

556,038. March 10, 1896; Michael H. Wilson, Brooklyn, N. Y.

Electric current carried to and from electrolyte by two falling streams of water flowing through or around metallic terminals above cell. Water streams may fall free or descend through vertical, perforated glass tubes, opening through top and bottom of cell. Partition depends from cover of cell, partially dividing salt solution.

560,518. May 19, 1896; Jules Meyrueis, Paris, France.

Diaphragm cells arranged in cascade. Pipes carry electrolyte through successive cathode compartments. Acidifies concentrated brine in anode compartments with hydrochloric acid. Delivers caustic solution to a boiler containing litharge, which dissolves and is re-precipitated as white lead by a stream of carbon dioxide. Residual liquor further carbonated and sodium bicarbonate crystallized out. Solution then returned to cells.